Valuing Mortality Risk Reductions in Homeland Security Regulatory Analyses

Final Report

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EXECUTIVE SUMMARY

When U.S. Customs and Border Protection (CBP) and other Department of Homeland Security (DHS) components develop economically significant regulations, they are required to assess the benefits, costs, and other impacts of alternative approaches. One of the many challenges inherent in these analyses involves determining the monetary value of the mortality risks averted by the regulations. This report develops recommendations for valuing these risks, reflecting the contributions of three leading experts: Dr. Joseph E. Aldy (Resources for the Future), Dr. James K. Hammitt (Harvard University), and Dr. Alan Krupnick (Resources for the Future).

Overview

The report begins by describing general guidance for valuing mortality risks in Federal regulatory analyses and discussing the current practices of agencies responsible for economically significant health and safety regulations. It summarizes recent valuation research and describes the effects of differences between the scenarios studied and those addressed in regulatory analyses. It then recommends a valuation approach for application in homeland security regulatory analyses, that can be implemented immediately based on the available research. The information in this report also identifies important research gaps and can be used to establish priorities for future work.

When a regulation or policy reduces the risk of premature mortality, Federal agencies rely on estimates of the value per statistical life (VSL) for monetary valuation. A "statistical life" reflects the aggregation of small changes in risks across individuals. For example, a 1 in 10,000 risk reduction that affects 10,000 individuals can be expressed as a statistical life (1/10,000 risk x 10,000 people = 1 statistical life).

Thus, the VSL reflects individual willingness to pay for small reductions in one's own risk of mortality, multiplied across a large population. For example, a $6 million VSL results if each member of a population of 10,000 is willing to pay $600 on average for a one in 10,000 decrease in his or her annual risk of dying ($600 x 10,000 people = $6 million). The VSL concept is frequently misunderstood; it is not the value of saving a particular individual's life.

Review of Existing Research

The VSL has been explored in a large number of research studies and is widely used in benefit-cost analyses. However, the available research generally addresses populations and risks that are dissimilar in some respects to those associated with terrorist events or other regulatory interventions. Thus regulatory analysts usually apply estimates derived from one scenario (e.g., job-related accidents) to a somewhat different scenario (e.g., homeland security regulations). This "benefit transfer" approach requires careful consideration of the quality of the available research (the data and methods used), and the suitability of the estimates (the extent to which they consider populations and risks that are similar to those addressed by the regulations). For some of these differences, the primary research results can be adjusted quantitatively to better fit the regulatory context. Otherwise, the potential implications of the differences must be discussed qualitatively, along with other sources of uncertainty that are difficult to quantify.

The U.S. Office of Management and Budget (OMB) is responsible for reviewing economically significant regulations and developing guidance for the supporting analyses. Its most recent guidance, published in 2003, suggests that the VSL ranges from roughly $1 million to $10 million based on available research. OMB provides agencies flexibility in determining the values that are most appropriate for their rules, as long as their approach is clearly described and justified. Federal agencies generally apply values from within the range described by OMB but vary in the exact estimates used, citing available literature reviews and meta-analyses as the sources for their estimates.

These meta-analyses employ statistical methods to combine the results from several VSL studies and to explore the factors that affect the variation in the values. The available analyses rely on studies which use relatively old data and methods and do not reflect more recent research. A 2007 expert panel review of the VSL meta-analyses indicated that improvements are needed in the inclusion criteria applied when selecting studies and in the statistical methods used.

Recently completed individual studies provide estimates that reflect newer data and improved analytic models. In particular, Dr. Joseph E. Aldy and Dr. W. Kip Viscusi have conducted a series of studies that examine the wage or salary premium received by workers who accept riskier jobs, using statistical methods to separate the effects of other factors (such as education and nonfatal job risks) on wages. The most recent of these studies (Viscusi 2004) suggests that the mean VSL in the U.S. is approximately $6.1 million (when inflated to 2007 dollars), which is within the range of estimates identified in previous literature reviews and meta-analyses.

This newer research, as well as the studies included in the VSL meta-analyses, address somewhat different scenarios than those addressed by the majority of major Federal regulations. For example, most studies consider risks faced by working-age individuals, while regulatory actions may affect risks among those who are younger and/or older. The studies focus largely on deaths from injuries, rather than on the illness-related deaths that are the focus of some regulatory interventions. In addition, most studies address deaths from relatively common causes (such as motor vehicle accidents), while Federal regulations may address deaths from events (such as terrorist acts) that are viewed as less voluntary, controllable, or familiar. Terrorist acts are also difficult to predict as well as low in probability but potentially catastrophic. Finally, older studies reflect individual willingness to pay for risk reductions based on real income levels (net of inflation) that are below current income levels, given that national productivity tends to increase over time.

The available empirical research supports quantitative adjustments for only some of these differences. OMB's guidance summarizes recent expert panel advice that endorses adjustments for changes in real income over time and for any time delays (or latency) between reductions in exposure and reductions in incidence. In addition, agencies may add the value of financial externalities (not included in estimates of individual willingness to pay for risk reductions) such as the medical costs associated with morbidity prior to death. Federal agencies vary in the extent to which they make these sorts of adjustments in their analyses.

Review of the differences between the scenarios studied and the scenarios of concern for homeland security rules suggests that risk perception may be the key factor affecting the transfer of these values. Available evidence suggests that the value of a risk reduction depends in part on its qualitative attributes; e.g., a risk of 1/10,000 is likely to be valued differently if it is associated with a terrorist attack rather than with a job-related accident. Research suggests that individuals are more likely to support government intervention for those risks which are perceived as less controllable, voluntary, and familiar. Only limited empirical research has been completed on the effects of such perceptions on the VSL however, and the available studies generally focus on hazards that may be less feared than terrorist acts. This research (which uses surveys or other stated preference methods) suggests that the value of averting more uncontrollable, involuntary, dreaded, or ambiguous risks may be higher than the value of more commonplace risks, by perhaps as much as a factor of two.

Recommendations

Based on review of current approaches and recent research and on advice from the experts involved in the supporting workshop, this report suggests that recent wage-risk studies (particularly Viscusi 2004) provide the most appropriate source for VSL estimates for application in the homeland security context. Analyses conducted for recent rules indicate that terrorists are most likely to target major urban areas with high concentrations of workers. Thus the averted mortality risks may accrue somewhat disproportionately to working-age individuals, similar to those included in the wage-risk studies. In addition, workers represent a sizable proportion of the overall U.S. population. To date, terrorists have tended to focus on types of attacks that primarily cause immediate death from trauma, which are more similar to the injury-related deaths included in the wage-risk studies than to the illness-related deaths that are of concern for environmental and many other regulations.

This approach results in a best estimate of $6.1 million in 2007 dollars (prior to adjustment for income growth), with a 95 percent confidence interval of $4.8 million to $7.6 million**,** based on Viscusi (2004) and supplementary analysis conducted by Dr. Aldy. While the source of these estimates is a newer study than the meta-analyses and literature reviews cited by many Federal agencies, the estimates themselves are similar to those currently used; i.e., within the $1.0 million to $10.0 million range defined in the OMB guidance.

These estimates should be adjusted for changes in real income over time, given the strong evidence that the VSL increases as income increases. According to Viscusi and Aldy (2003), wage-risk studies suggest that the relationship between income and the VSL results conservatively in a mean income elasticity of 0.47. In other words, for each one percent change in real income, the VSL is expected to increase by 0.47 percent. Their analysis indicates that the 95 percent confidence interval for this income elasticity estimate ranges from 0.15 to 0.78. These estimates are similar to those used by other Federal regulatory agencies as well as those estimated in other studies, but reflect a somewhat tighter range. If the range of VSL estimates reported above is adjusted for real income growth (using an elasticity estimate of 0.47) as well as for inflation, the resulting values include a best estimate of $6.3 million, with a range of $4.9 million to $7.9 million.

The available studies do not directly assess the differences between individuals' willingness to pay to avert the mortality risks associated with terrorism in comparison to the risks associated with job choices or other less dreaded causes. Thus there is substantial uncertainty regarding this relationship. A review of the available evidence (conducted by Dr. Hammitt for this report) suggests that the differences may be relatively large. Thus DHS may wish to illustrate the effects of these differences in sensitivity analyses. For example, based on the available research, this sensitivity analysis could rely on a VSL estimate that is twice the estimate used in the main analysis, with a mean value of $12.6 million, if adjusted for both inflation and income growth.

Some homeland security rules may affect different population subgroups or different types of risks, in which case the information in this report can be used to make appropriate quantitative adjustments to the VSL or to discuss related uncertainties in qualitative terms. For example, if an attack is likely to lead to deaths from lingering illness such as cancers (e.g., from exposure to radiological, biological, or chemical hazards), the VSL can be adjusted for any latency or time lag between exposure and incidence, and for the costs associated with any morbidity period that precedes death, using simple adjustments developed by other regulatory agencies. More research would be needed to quantify the effects of most other differences, but their potential impact can be discussed based on theory and the limited empirical data available.

1.0 INTRODUCTION AND BACKGROUND

U.S. Customs and Border Protection (CBP), within the Department of Homeland Security (DHS), is responsible for preventing terrorists and terrorist weapons from entering the United States while facilitating the flow of legitimate trade and travel. When a CBP initiative is expected to result in an economically significant regulation, the agency is required to assess the benefits, costs, and other impacts of alternative approaches. Often the most difficult task is determining the likely impact of the regulations on terrorist events. Another of the many analytic challenges involves estimating the value of the health risk reductions associated with a decrease in the number, type, or severity of attacks.[1]

This report recommends an approach for valuing these health effects, focusing on mortality risks.[2] While designed to support on-going CBP regulatory analyses, the approach is also applicable to many of the anti-terrorism regulations promulgated by other DHS components. It is based on recent research and guidance and reflects the results of a workshop involving three leading experts: Dr. Joseph E. Aldy (Resources for the Future), Dr. James K. Hammitt (Harvard University), and Dr. Alan Krupnick (Resources for the Future).[3]

The value of mortality risk reductions, usually referred to as the value per statistical life (VSL), has been widely studied. However, this research generally addresses risks that are dissimilar in some respects to the risks associated with terrorist events. Thus regulatory analysts usually apply estimates derived from one scenario (e.g., job-related accidents) to a somewhat different scenario (i.e., homeland security regulations). This "benefit transfer" approach requires careful consideration of a number of factors, particularly (1) the quality of the available research (e.g., the data and methods used), and (2) the suitability of the estimates (e.g., the extent to which they consider populations and risks that are similar to those addressed by the regulations). While in some cases it may be possible to adjust the primary research results to better fit the regulatory context, these analyses generally require both quantitative and qualitative exploration of the implications of remaining uncertainties.

The use of a benefit transfer approach for valuing mortality risks in regulatory analysis is well-established. Federal agencies often address risks that differ from those most frequently studied, and approaches for applying the available research are discussed in detail in current government-wide guidance and recent expert panel reports. However, the approaches used by other agencies may not be entirely appropriate for homeland security rules. They address different types of risks, in some cases affecting different types of populations. In addition, they do not yet fully incorporate the most recent research and expert panel advice. Thus CBP

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[1] For convenience, the term "risk reductions" is used throughout this report. These analyses also include consideration of any risk increases associated with the regulations.
[2] An earlier report (Robinson 2007a) provides a preliminary review of approaches for valuing nonfatal injury risks.
[3] The other workshop participants also contributed significantly to the recommendations in this report: David Houser and Charlotte Oliver (Office of General Counsel, DHS), Elena Ryan and Brett Gelso (U.S. Customs and Border Protection, DHS), and Jennifer Baxter and Henry Roman (Industrial Economics, Incorporated).

commissioned this report and the associated expert workshop to develop estimates tailored to its rules that reflect the current state of the art.

Given this framework, this introductory chapter begins with an overview of the types of mortality risks addressed by CBP regulations. It then introduces the VSL concept in more detail. The second chapter summarizes relevant Federal guidance and describes the approaches currently used by regulatory agencies. The third chapter provides more information on studies that can be used to develop base VSL estimates, while the fourth discusses issues related to adjusting these estimates for scenario differences. The fifth chapter concludes by describing the VSL estimates recommended for use in homeland security regulatory analyses, based on currently available research.

1.1 The Regulatory Context

DHS was formed in January 2003, bringing together 22 disparate agencies to focus on homeland security. According to annual reports issued by the U.S. Office of Management and Budget (OMB), it finalized seven economically significant regulations targeted on averting terrorist acts through the end of September 2006 (OMB 2005, OMB 2006, OMB 2007).[4] These rules are briefly summarized in Exhibit 1.1, which is followed by a discussion of more recent DHS regulatory analyses.

[4] The exhibit excludes homeland security rules promulgated by Federal agencies other than DHS and also excludes DHS rules that are not focused on preventing terrorist events (e.g., maritime safety rules issued by the U.S. Coast Guard). "Economically significant" rules include those that have a predicted annual impact on the economy of $100 million or more or other significant effects (EOP 1993).

Exhibit 1.1 ECONOMICALLY SIGNIFICANT HOMELAND SECURITY RULES FINALIZED BETWEEN JANUARY 2003 AND SEPTEMBER 2006			
DHS Agency (FR cite, year)[a]	**Rule**	**Annual Costs[b] (2001 dollars)**	**Primary Benefits**
Customs and Border Protection (68FR68140, 2003)	Required Advance Electronic Presentation of Cargo Information	\$334 - \$2,094 million	Provides more information on cargo shipments to improve security.[c]
Coast Guard (68FR60472, 2003)	Area Maritime Security	\$66 million[d]	Reduces the risk and impact of a transportation security incident.[e]
Coast Guard (68FR60483, 2003)	Vessel Security	\$188 million[d]	Reduces the risk and impact of a transportation security incident.[e]
Coast Guard (68FR60515, 2003)	Facility Security	\$743 million[d]	Reduces the risk and impact of a transportation security incident.[e]
Border and Transportation Security Directorate (69FR53318, 2004)	Authority to Collect Biometric Data from Additional Travelers	\$27 million[f]	Improves identification of travelers who may pose security threats.
Customs and Border Protection (70FR17820, 2005)	Electronic Transmission of Passenger and Crew Manifests	\$127 million	Assists in effective inspection and control of passenger and crew members and enforcement of related laws.
Transportation Security Administration (71FR30478, 2006)	Air Cargo Security Requirements	\$185 - \$187 million	Prevents unauthorized persons and destructive materials from being placed into air cargo.

Sources: OMB 2005, OMB 2006, OMB 2007, and the Federal Register notices cited.
Notes:
a. "FR" indicates the Federal Register volume and page number for the final rule.
b. OMB estimates.
c. Also streamlines border crossings, providing \$22 million in time savings and reduced fuel costs as well as other benefits.
d. Annualized at 7 percent discount rate over 10 years; excludes start-up costs where applicable.
e. Assessed in terms of risk points using the National Risk Assessment Tool (see Ryan 2007).
f. Includes start-up costs annualized at a 7 percent discount rate over 7 years.

As suggested by the exhibit, some homeland security rules contain relatively broad security requirements while others focus more narrowly on particular types of targets and/or means of attack. While the supporting analyses for these initial DHS rules provide quantified cost estimates, the primary benefits – i.e., their effects on the likelihood and impacts of terrorist events – are not expressed in monetary terms. Benefits are generally discussed qualitatively, or (in the case of Coast Guard rules) assessed using risk scales that are not translated into dollar estimates. These practices reflect the enormous difficulties inherent in estimating the baseline (pre-regulatory) likelihood of terrorist attacks as well as in determining the effects of these regulations on the baseline risks.

More recently, DHS has made significant progress in assessing the benefits of its rules. It now conducts breakeven analysis to determine the reduction in terrorist events that would be needed for the benefits of each rule to equal or exceed its costs. For example, in the analysis supporting its REAL ID regulations (DHS 2007), which establish minimum standards for driver's licenses and identification cards, DHS considered the extent to which the rule would need to reduce the annual probability of another 9/11 attack for its benefits to be commensurate with its costs.[5]

A more complex, multi-scenario approach was applied to support CBP's proposed Western Hemisphere Travel Initiative rule, which would establish documentation requirements for international land travelers (IEc 2007a). RAND's Center for Terrorism Risk Management Policy conducted a breakeven analysis using Risk Management Solutions' (RMS') Probabilistic Terrorism Model (Latourrette and Willis 2007).[6] This model was created for the insurance industry, and estimates the likelihood of different types of attacks as well as the consequences of each attack based on a structured expert elicitation process.

The RMS model focuses on a small number of cities, assuming that attacks are most likely to occur in major urban areas. Within each city, the model groups types of targets by the relative probability of attack. These targets include, for example, government buildings, airports, power plants, and other types of facilities, as well as those with significant iconic value. In addition, the model considers a number of different attack modes, each of which is assigned a relative likelihood based in part on the difficulty of implementation. Examples of these attack modes include shooting down an aircraft with a surface-to-air missile, exploding conventional or nuclear bombs of various sizes, setting major fires, or releasing substances such as sarin gas, anthrax, or smallpox. The model also estimates the consequences of the attacks, including the geographic areas covered, the damages to buildings and other properties, and the numbers of injuries and deaths. For the breakeven analysis, the model is used to quantify these consequences, which are then converted to a dollar value and compared to the costs of the rule. The results indicate the reduction in the likelihood of attacks needed for the benefits of the rule to equal or exceed its costs.

Another recent example is the approach developed for CBP's proposed Importer Security Filing and Additional Carrier Requirements rule, which would mandate the electronic reporting of additional data on cargo shipments destined for the United States. In the analysis (IEc 2007b), CBP considered three hypothetical scenarios: a 12-day closure of all West Coast ports, a nuclear attack in a major urban area, and a biological attack involving the release of smallpox in an urban area. The breakeven analysis compared the costs of the rule to the reduction in the likelihood of attack needed for benefits to equal or exceed costs, considering each type of attack individually.

Review of these analyses suggests that it is difficult to characterize the populations and risks affected by these rules in detail. In general, it appears that the population affected is likely to be urban, and may disproportionately include working-age adults given the focus on targets that serve as places of employment. In addition, the types of mortality risks addressed appear to more often result immediately from trauma than from lingering illness. However, other population groups and types of mortality risks also may be affected.

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[5] DHS also considered ancillary benefits, such as the effect of the requirements on identity theft and unqualified drivers.
[6] This study was recently published as Willis and Latourette (2008).

Thus in applying the benefit transfer framework introduced above, this report assumes that: (1) most homeland security rules are likely to address multiple attack scenarios; (2) averted deaths would most likely result immediately from severe injury; and (3) working-age individuals may be disproportionately affected. However, the report also discusses the implications of other scenarios which may be more narrowly focused on particular targets or modes of attack, may include deaths from longer term impacts (e.g., associated with chronic illness from exposure to chemical, biological, or radiological contaminants), and/or may have larger effects on other age groups.

1.2 The Value of Statistical Life[7]

When conducting regulatory analysis, agencies estimate the value that individuals place on small changes in their own mortality risks, and then sum these values across the risks addressed by the rulemaking. Economists apply the concept of a "statistical life" to describe the aggregation of these small risk changes. For example, a regulation that reduces risks by one in 100,000 on average throughout a population of 100,000 individuals can be described as saving one statistical life, as can an effort that achieves an average risk reduction of one in 10,000 throughout a population of 10,000. The concept of a statistical life is often misunderstood; its value is not equivalent to the value of saving the life of a particular individual.[8]

The value of these small reductions in mortality risks usually takes the form of a "value per statistical life" (VSL). Following the above example, if each member of the population of 100,000 was willing to pay $50 on average for a one in 100,000 decrease in his or her risk of dying during the year, the corresponding VSL would be $50 x 100,000 or $5 million.[9] If each was instead willing to pay $50 for a one in 10,000 decrease in annual mortality risk, the corresponding VSL would be $500,000. The VSL represents an individual's willingness to trade income (or wealth) for small changes in the likelihood of survival; e.g., to use funds for risk reductions rather than to purchase other goods or services.

The valuation of these risk reductions is based on neoclassical economic welfare theory, starting with the assumption that individuals derive utility, or a sense of well-being, from the goods and services they consume. In this context, the VSL is most appropriately measured by the change in income that has the same effect on utility as the risk reduction. This trade-off relates to both current and future well-being. Reducing current mortality risks increases the likelihood that an individual will survive to enjoy future consumption and leisure; however, the expenditure of income on the risk reduction will reduce is availability for current consumption (and perhaps reduce leisure if the individual works more hours to finance the expenditure). More formally, the

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[7] See Hammitt (2000) and Hammitt (2008a) for a more detailed and technical discussion of these concepts.

[8] In the United Kingdom, the term "Value of Preventing a Statistical Fatality" (VPF) is increasingly used instead of VSL; however, the concepts are identical.

[9] Conceptually, changing the probability of surviving the current period also changes the likelihood of surviving future periods; i.e., shifts the entire survival curve of the affected individuals. (Survival curves plot the relationship between age and the likelihood of mortality, and can be used to illustrate the cumulative effects of changes in risk over time.) Most studies use a simpler approach and focus instead on a small annual change in the risk of death.

economic model most often used to explore the relationship between these factors and the VSL is the life-cycle consumption model, as described in detail in elsewhere (e.g., Shepard and Zeckhauser 1982; Cropper and Sussman 1990). This model assumes that individuals make choices based on their expected utility from future consumption, given their expected future income and probability of survival, and taking into account their rate of time preference (i.e., their discount rate) as well as other factors.

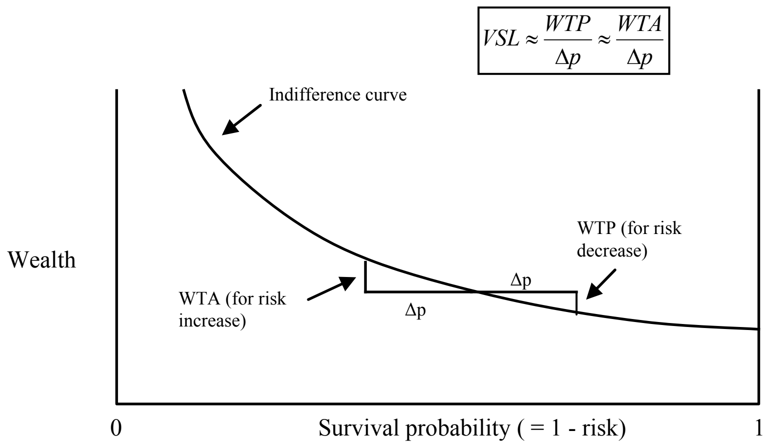
Because utility cannot be measured directly, economists rely instead on estimates of willingness to pay (WTP) or at times, willingness to accept (WTA) compensation, for valuation. WTP is the maximum amount of money an individual would voluntarily exchange to obtain an improvement, given his or her budget constraints. WTA is the least amount of money he or she would accept to forego the improvement.[10] While these two measures are not necessarily equal, analysts often rely on estimates of WTP for valuation due to concerns about the accuracy and reliability of the methods available for estimating WTA. For small changes in mortality risks, the difference between WTP and WTA is expected to be relatively minor.

The VSL concept is illustrated more formally in Exhibit 1.2 (Hammitt 2008a). Wealth is plotted along the vertical axis, and the probability ("p") of survival is plotted along the horizontal axis. The curved line represents an individual's indifference curve; i.e., the set of points (or combinations of wealth and survival probabilities) which he or she considers equivalent. In other words, the individual would consider him or herself equally well-off at each point along this curve. For each change in survival probability ("Δp"), WTP or WTA is measured by the vertical distance between the two points on the indifference curve. Because the VSL is the value of a "statistical" case; i.e., sums the values for small changes in risk, it can be calculated as the individual's average WTP or WTA divided by the change in survival probability.

[10] See Freeman (2003) for more information on these concepts and measures.

Exhibit 1.2

THE VALUE OF STATISTICAL LIFE: TRADE-OFF BETWEEN WEALTH AND SURVIVAL PROBABILITY



Source: Replicated from Hammitt (2008a).

Intuitively, one expects that individual WTP would increase as the size of the risk reduction increases, and would be close-to-proportional when the incremental risk change is small. However, this relationship may not be linear for large risk changes; i.e., the value of a single 1 in 1,000 risk reduction may not be equivalent to 10 times the value of a 1 in 10,000 risk reduction. Under standard assumptions, economic theory suggests that individual WTP will decrease by some (unknown) amount with each incremental increase in the risk reduction (see Hammitt 2000, Hammitt and Treich 2007). Evidence from empirical studies (e.g., Viscusi and Aldy 2003) also suggests that the relationship is concave rather than linear.[11] When expressed as the VSL rather than as WTP for a small risk change (i.e., aggregated across individuals to estimate the value per statistical case), Viscusi and Aldy indicate that this relationship results in somewhat larger VSL estimates for smaller incremental risk reductions.

As discussed in more detail later in this report, the relationships illustrated in Exhibit 1.2 may be influenced by a number of other factors, such as income or wealth, total mortality risk from all causes, age or life expectancy, and current or potential future health status (or extent of

[11] As discussed later, some studies show significantly non-proportional relationships, which may reflect problems with how the risk change was communicated (see, for example, Corso, Hammitt, and Graham 2001)

impairment). In addition, individuals may place different values on risks with different characteristics. For example, the value of a 1/10,000 risk reduction may differ depending on whether it results immediately from injury or from a lingering illness, or on whether it is caused by a hazard viewed as voluntarily incurred, under the control of the affected individual, and/or greatly feared.

Economists generally estimate the value of these mortality risk reductions (and of other goods or services not directly bought and sold in markets) using revealed or stated preference methods.

- *Revealed preference* methods use data from market transactions or observed behavior to estimate the value of related goods. Wage-risk studies (also referred to as compensating wage differential or hedonic wage studies) are a type of revealed preference research that is commonly used to estimate the VSL. In these studies, researchers compare earnings across workers in different occupations or industries who face varying levels of on-the-job risks, using statistical methods to control for the effects of other factors (such as education or nonfatal job risks) on their wages.[12]

- *Stated preference* methods involve asking respondents how they would behave in a hypothetical market, allowing researchers to investigate individual WTP for nonmarketed goods. They include contingent valuation surveys, which ask respondents to report their WTP for risk reductions associated with specific scenarios, and conjoint analyses (or choice experiments), which disaggregate the attributes of the scenarios and explore related trade-offs.

Each type of study has advantages and limitations. For example, revealed preference studies rely on market data but may address scenarios that differ in significant respects from those of concern in regulatory analyses. Stated preference studies allow researchers to better tailor the scenario to the risks of concern but are hypothetical in nature. As a result, analysts often use a range of estimates from different studies for valuation.

Agencies face several challenges in applying estimates from these studies. Within the benefit transfer framework, they must determine which studies are most appropriate for the particular regulatory context, adapt or adjust the estimates from these studies if possible to better fit the scenario of concern, and assess the implications of uncertainties. These steps involve a number of complex considerations because the available VSL research addresses scenarios that

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[12] Studies that consider averting behavior (or the demand for consumer safety products) also have been used to estimate the VSL; see Blomquist 2004 for a recent review. Researchers (e.g., Viscusi 1992, Viscusi 1993) often argue that these studies are less suitable for valuation than the available wage-risk and contingent valuation studies, because the relationship of these behaviors to willingness to pay for risk reductions is often unclear and the results are less precise than those estimated using other methods. For example, the size of the risk reduction that results from the averting behavior (e.g., from wearing a motorcycle helmet or using a seatbelt) may be hard to estimate. In addition, averting behavior is often motivated by a number of different concerns, and it can be difficult to separate out the portion of the total value that is attributable to risk avoidance. For example, individuals may choose to drink bottled water for convenience as well as to avert perceived health risks.

differ in several respects from the scenarios addressed by Federal regulations. The implications of these differences are discussed in Chapter 4 of this report.

One adjustment for these differences that is frequently discussed, and hence worth introducing here, is the conversion of VSL estimates to estimates of the value per statistical life year (VSLY). This latter value is usually derived by dividing the VSL by the discounted expected number of life years remaining for the average individual studied. In other words, this approach assumes that the value of each remaining life year is constant, using discounting to reflect time preferences. The resulting VSLY is then applied to the expected number of discounted life years saved by a regulation (i.e., to the predicted increase in discounted life expectancy) to estimate the value of mortality risk reductions.[13]

Because the number of years of life extension is closely related to the life expectancy and age of the affected individuals, VSLY is often interpreted as an approach for adjusting VSL to reflect age differences. For example, this approach has been applied in some contexts (such as air pollution regulations) where the risk reductions disproportionately affect individuals who are older than the working-age individuals considered in the compensating wage studies.[14] However, as discussed in more detail later in this report, both economic theory and empirical studies suggest that the relationship between VSL and life expectancy or age is more complex than indicated by this simple VSLY calculation. In addition, because the application of a VSLY approach suggests that saving the life of an elderly individual is worth less than saving the life of a younger individual (who has more remaining life years), the use of VSLY has been contentious when applied in regulatory analysis.

[13] An early example of the use of VSLY estimates in policy analysis is provided in a 1997 EPA report. In this case, EPA assumed that the VSL was $4.8 million (in 1990 dollars), the remaining life expectancy averaged 35 years for the individuals included in the underlying studies, and the VSL estimate reflected a 5 percent discount rate, resulting in a VSLY estimate of $293,000. If the average individual whose life is extended by the program would survive for an additional 14 years (as a result of reduced exposure to pollutants), the present value of the risk reductions would be $2.9 million (i.e., the discounted value of 14 years x $293,000 per year). In other words, under this approach the total value of the mortality risk reduction would be $4.8 million for a younger individual who would survive for 35 additional years, and $2.9 million for an older individual who would survive for only 14 more years. As discussed later, EPA no longer uses VSLY estimates in its analyses.

[14] VSLY estimates have also been used to assign monetary values to quality-adjusted life years (QALYs) when valuing nonfatal risks in regulatory analysis. However, an expert panel recently recommended against this approach; see Hammitt (2002a), Robinson (2004), and IOM (2006) for more discussion of this issue. A constant VSLY is also often used to value QALYs in the health economics literature (e.g., when comparing different options for medical treatment); see Grosse (2008) for a related review.

2.0 CURRENT FEDERAL AGENCY PRACTICES

While relatively few Federal agencies promulgate major regulations that result in significant reductions in mortality risks, the impacts of these regulations are substantial. These agencies generally follow U.S. Office of Management and Budget (OMB) guidance for valuation, but vary somewhat in the estimates used and the adjustments made to address scenario differences. Only limited empirical evidence is available on the likely variation in values attributable to the differences in the types of risks regulated by each agency. The cross-agency diversity in values instead reflects reliance on different reviews of the literature as well as different decisions related to updating or adjusting these estimates.

This chapter first discusses the OMB guidance, then describes the approaches used by several agencies. It summarizes the evolution of the estimates used by the U.S. Environmental Protection Agency (EPA), which has expended substantial effort on conducting related research and refining its approach. It then describes the estimates used by the National Highway Traffic Safety Administration (NHTSA) in the U.S. Department of Transportation (DOT), including a recent update to the DOT-wide guidance. The following section discusses the approaches used by other agencies, including the Food and Drug Administration (FDA) in the U.S. Department of Health and Human Services (HHS) and the Occupational Safety and Health Administration (OSHA) in the U.S. Department of Labor (DOL). It also summarizes the approach used in a breakeven analysis recently completed by U.S. Customs and Border Protection (CBP) in the U.S. Department of Homeland Security (DHS). The final section then provides the conclusions of this review.

2.1 Government-Wide Guidance

Under Executive Order 12866, *Regulatory Planning and Review* (EOP 1993, as amended by Executive Orders 13258 (2002) and 13422 (2007)), Federal agencies are required to assess the costs, benefits, and other impacts of major regulations. These analyses are required for regulations that are economically significant; i.e., that have a predicted annual impact on the economy of $100 million or more or other significant effects. Guidance for preparing these analyses is provided by OMB in Circular A-4, *Regulatory Analysis* (OMB 2003), which explicitly discusses the approach for valuing mortality risk reductions and allows agencies some discretion in determining which VSL estimate best fits their regulations.

OMB is responsible for coordinating and reviewing regulatory analyses across Federal agencies, and designed Circular A-4 both to help agencies conduct good analyses and to promote consistency across agencies.[15] While OMB suggests preferred practices, it allows agencies to exercise judgment in conducting their analyses as long as they provide sufficient justification for their approach. Ultimately, each published regulatory analysis is the result of negotiations between OMB and the agency during the OMB review process.

In Circular A-4, OMB discusses a number of analytic issues, such as identifying alternative policy or regulatory strategies, assessing different types of costs and benefits, and

[15] See Robinson (2004) for discussion of the evolution of this guidance.

considering the distribution of the impacts. It includes sections that directly address benefit valuation (including principles that agencies should consider in evaluating the available research) as well as related topics such as selecting a discount rate and assessing uncertainty.

For premature mortality, the OMB guidance indicates that estimates of WTP for small changes in risk (i.e., the value per statistical life –VSL) are generally most relevant for regulatory benefit-cost analysis. It notes that the available research, which includes numerous studies, suggests that the VSL is generally between roughly $1 million and $10 million (no dollar year reported). These estimates are subject to continued research and debate, and the guidance suggests that agencies should use the values that they "consider appropriate for their regulatory circumstances" and should clearly explain the "selection of estimates and any adjustments of the estimates to reflect the nature of the risk being evaluated" (OMB 2003, pp. 30-31).

OMB also discusses the options for adjusting these VSL estimates to better match the regulatory scenario; i.e., to address differences between the populations and types of risks assessed in the research literature and the context for the rulemaking. The guidance indicates that the available research supports quantitative adjustments only for changes in income over time and for time lags in the incidence of health impacts.[16] OMB cautions agencies on applying quantitative adjustments for the age of those affected, but suggests that both VSL and value per statistical life year (VSLY) estimates be presented. (These VSLY estimates, as introduced in Chapter 1 and discussed in more detail in Chapter 4, adjust for differences in the expected years of life extension, which are closely related to age.) However, OMB suggests that agencies use larger VSLY estimates for older individuals "because senior citizens face larger overall health risks from all causes and they may have accumulated savings to spend on their health and safety" (OMB 2003, p. 30).[17]

Relatively few economically significant rules are finalized each year that are subject to these requirements, but their impact is large. For example, in fiscal year 2006, OMB reviewed only five final rules that (1) were economically significant, (2) included monetized estimates of health or safety benefits, and (3) were subject to Executive Order 12866 (OMB 2007).[18] OMB calculated that the costs of these rules total approximately $3.6 billion to $4.0 billion per year, and that their monetized benefits total between $6.0 billion and $44.0 billion (2001 dollars). The majority of these benefits are attributable to a single regulation – an EPA rule regarding national

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[16] In its discussion of the valuation of nonfatal risks, OMB also notes that it may be appropriate to add "the net financial externalities associated with poor health such as net changes in public medical costs and any net changes in economic production that are not experienced by the target population" to the extent that these are not reflected in the estimates of individual WTP (OMB 2003, p. 29).

[17] There is not consensus on the relationship between VSLY and age in the theoretical or empirical literature (see Hammitt 2007, Aldy and Viscusi 2007, and Krupnick 2007). For example, one recent study suggests that the VSLY begins to decline as working individuals reach their early 50s (see Aldy and Viscusi forthcoming).

[18] Several independent agencies are not subject to OMB regulatory review under Executive Order 12866. Of these agencies, only the Consumer Products Safety Commission and the Nuclear Regulatory Commission tend to promulgate major rules with significant health-related benefits (Robinson 2004, Robinson 2007b, OMB 2007). These agencies generally follow the analytic approaches suggested in OMB Circular A-4.

attainment standards for particulate matter in ambient air – and the value of reduced mortality risks accounted for most (almost 90 percent) of its monetized benefits (EPA 2006a). Data for other years show a similar pattern; EPA's air pollution rules account for a significant proportion of all economically significant health and safety regulations and their benefits are attributable primarily to reductions in premature mortality (Robinson 2004, Robinson 2007b). (These counts do not include homeland security rules, which (as discussed in Chapter 1) generally have not been accompanied by monetized estimates of health-related benefits.) The approaches used in these analyses to value mortality risk reductions are described below.

2.2 EPA's Approach

Historically, EPA has been responsible for the majority of the economically significant health and safety rules that lead to mortality risk reductions, both in terms of the number of rules and the size of the estimated benefits (OMB 2007). As a result, EPA has devoted considerable attention to developing methods for valuing these risks. Most of these rules address air pollutants and have been promulgated by its Office of Air and Radiation. EPA's Office of Ground Water and Drinking Water also has promulgated several economically significant rules that provide mortality risk reductions.

For many years, EPA relied on VSL estimates derived largely from work completed in the early 1990s to support its retrospective and prospective analyses of the impacts of the Clean Air Act (ultimately published as EPA 1997 and EPA 1999, and summarized in more detail in Industrial Economics, Incorporated (IEc) 2001). More recently, it has begun to rely on the results of VSL meta-analyses for some of its regulatory assessments, and its approach continues to evolve as the result of new research and expert review.

EPA's original approach was based on research conducted by Viscusi (1992, 1993), from which it identified 26 VSL estimates suitable for use in its analyses. These estimates were derived from risk and earnings data collected largely in the late 1960s through early 1980s. Of the 26 estimates, 21 were from wage-risk studies and five were from contingent valuation studies. The mean VSL estimates ranged from $0.6 million to $13.5 million in each study, with an overall mean of $4.8 million across studies (1990 dollars). While the wage-risk studies provided values scattered throughout this range, the estimates from the contingent valuation studies clustered towards the lower end. These 26 estimates (which in some cases include more than one estimate from a single study) are summarized in Exhibit 2.1 in 1990 dollars. If inflated to 2007 dollars, the range becomes $1.0 million to $21.4 million, with a mean of $7.6 million.[19]

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[19] Unless otherwise referenced, values in this report are inflated using the Consumer Price Index - All Urban Consumers (CPI-U), reported at http://www.bls.gov/CPI/.

Exhibit 2.1

SELECTED CHARACTERISTICS OF VSL STUDIES USED BY EPA
(1990 dollars)

Study	**Mean VSL Estimate**	**Valuation Method**	**Population Studied**	**Average Age**[b]	**Average Income**[a,b]	**Type of Risk**	**Mean Risk**[a,b]
Kneisner and Leeth (1991)	$0.6 million	Wage-Risk	U.S. manufacturing workers	37 years	$26,226	Job-related	40/100,000
Smith and Gilbert (1984, based on Smith, 1983)	$0.7 million	Wage-Risk	U.S. metropolitan area workers	NR	NR	Job-related	NR
Dillingham (1985)	$0.9 million	Wage-Risk	U.S. workers	36 years	$20,848	Job-related	10/100,000
Butler (1983)	$1.1 million	Wage-Risk	S. Carolina workers	NR	NR	Job-related	5/100,000
Miller and Guria (1991)	$1.2 million	Contingent Valuation	New Zealand residents	NR	NR	Road safety	NR
Moore and Viscusi (1988)	$2.5 million	Wage-Risk	U.S. workers	37 years	$19,444	Job-related	5/100,000
Viscusi, Magat, and Huber (1991a)	$2.7 million	Contingent Valuation	U.S. residents	33 years	$43,771	Auto accidents	1/100,000
Marin and Psacharopoulos (1982)	$2.8 million	Wage-Risk	U.K. workers	NR	$11,287	Job-related	10/100,000
Gegax, Gerking and Schulze. (1991)	$3.3 million	Contingent Valuation	U.S. workers	NR	NR	Job-related	70/100,000
Kneisner and Leeth (1991)	$3.3 million	Wage-Risk	Australian manufacturing workers	NR	$18,177	Job-related	10/100,000
Gerking, de Haan, and Schulze (1988)	$3.4 million	Contingent Valuation	U.S. workers	NR	NR	Job-related	NR
Cousineau, Lecroix, and Girard (1992)	$3.6 million	Wage-Risk	Canadian workers	NR	NR	Job-related	1/100,000
Jones-Lee (1989)	$3.8 million	Contingent Valuation	U.K. residents	NR	NR	Auto accidents	NR
Dillingham (1985)	$3.9 million	Wage-Risk	U.S. workers	36 years	$20,848	Job-related	8/100,000
Viscusi (1978, 1979)	$4.1 million	Wage-Risk	U.S. workers	40 years	$24,834	Job-related	10/100,000
R.S. Smith (1976)	$4.6 million	Wage-Risk	U.S. workers	NR	NR	Job-related	10/100,000
V.K. Smith (1983)	$4.7 million	Wage-Risk	U.S. workers	NR	NR	Job-related	NR
Olson (1981)	$5.2 million	Wage-Risk	U.S. workers	37 years	NR	Job-related	10/100,000
Viscusi (1981)	$6.5 million	Wage-Risk	U.S. workers	NR	$17,640	Job-related	10/100,000
R.S. Smith (1974)	$7.2 million	Wage-Risk	U.S. workers	NR	$22,640	Job-related	NR
Moore and Viscusi (1988)	$7.3 million	Wage-Risk	U.S. workers	37 years	$19,444	Job-related	8/100,000
Kneisner and Leeth (1991)	$7.6 million	Wage-Risk	Japanese manufacturing workers	NR	$34,989	Job-related	3/100,000

Exhibit 2.1

SELECTED CHARACTERISTICS OF VSL STUDIES USED BY EPA
(1990 dollars)

Study	Mean VSL Estimate	Valuation Method	Population Studied	Average Age[b]	Average Income[a,b]	Type of Risk	Mean Risk[a,b]
Herzog and Schlottman (1990)	$9.1 million	Wage-Risk	U.S. manufacturing workers	NR	NR	Job-related	NR
Leigh and Folson (1984)	$9.7 million	Wage-Risk	U.S. workers	NR	$27,693	Job-related	10/100,000
Leigh (1987)	$10.4 million	Wage-Risk	U.S. workers	NR	NR	Job-related	NR
Garen (1988)	$13.5 million	Wage-Risk	U.S. workers	NR	NR	Job-related	NR

Source:
EPA (1997), Table I-1, and IEc (2001), Exhibit 4-2.
Notes:
a. Average income and risk level are based on Viscusi 1993, Tables 2 and 6, and additional review of the individual studies.
b. "NR" indicates "not reported;" however, many of these studies are based on data sources that are the same or similar to those for which these variables are reported.

Most, but not all, of these estimates rely on studies of U.S. workers and focus on accidental job-related deaths. On average, the workers studied are in their mid- to late-thirties and have incomes varying from slightly above $10,000 to over $40,000 (in 1990 dollars). The magnitude of the risks average from about one in 100,000 to about seven in 10,000 annually, and tend to cluster around one in 10,000.

In addition to considering different income groups and risk changes, these studies vary in other ways that may affect their quality and/or their suitability for use in different types of regulatory analyses. For example, they differ in the sample sizes used, the characteristics of the underlying data sources, and the extent to which they adjust for potentially significant variables such as the availability of workers' compensation. They were originally designed to address several different concerns, such as the effects of gender, unionization, job type, location, and/or risk perceptions on VSL estimates. The nature of these concerns in turn affected the data incorporated into the study design and the variables used in the statistical analysis.

The approach used for the Clean Air Act analysis, based on these 26 VSL estimates, was ultimately incorporated into EPA's *Guidelines for Preparing Economic Analysis* (EPA 2000a). For many years, EPA relied on this range in its regulatory analyses, adjusted as needed for inflation.

Recently, researchers have completed several meta-analyses that use statistical methods to combine data from various VSL studies, including analyses by Mrozek and Taylor (2002), Viscusi and Aldy (2003), and Kochi et al. (2006). Each group of researchers uses a somewhat different approach and reports different ranges of estimates. Mrozek and Taylor report a best estimate of $1.5 million to $2.5 million (1998 dollars); Viscusi and Aldy report means ranging from $5.5 million to $7.6 million (2000 dollars); and Kochi et al. report a mean of $5.4 million (2000 dollars) with a standard deviation of $2.4 million. Only the Kochi et al. analysis includes stated preference research; the other two studies rely on data from wage-risk studies. These meta-analyses are discussed in more detail in Chapter 3.

EPA has begun using the results of these meta-analyses when assessing the impacts of its air pollution rules, while continuing to rely on the 26 estimates for other rules such as those addressing drinking water. When applying the meta-analysis results (e.g., in EPA 2006a), EPA notes that it uses a normally-distributed range with a 95 percent confidence interval between $1 million and $10 million, and a mean of $5.5 million (1999 dollars).[20] It attributes the $1 million and $10 million values respectively to the lower end of the interquartile range from Mrozek and Taylor (2003) and the upper end of the interquartile range from Viscusi and Aldy (2003).

When instead using the 26 VSL estimates from the EPA guidance (e.g., in assessing its drinking water rules), the agency assumes the values are best described by a Weibull distribution, which (inflated and adjusted for real income growth) had a mean of $7.8 million, a 5th percentile value of $1.2 million and a 95th percentile value of $17.9 million (2003 dollars, EPA 2005a).[21] Thus the VSL estimates (in 1999 dollars) used by EPA's Office of Air and Radiation coincide with the range of $1 million to $10 million included in OMB's guidance, while the estimates based on EPA's 2000 guidance are larger with high end values that exceed the top of the OMB range.

Over time, EPA's approach has been subject to extensive public comment and expert review. EPA staff and consultants have drafted a number of papers summarizing related issues for consideration by independent committees of its Science Advisory Board (including Schmalensee et al. 1993, Stavins et al. 1999, Stavins et al. 2000, Cropper et al. 2001, Cameron et al. 2004, and Cropper et al. 2007). Most of these reviews suggested that additional research was needed to refine the base VSL estimates. The latest report (Cropper et al. 2007) also recommends a number of specific improvements to the approaches used in the available meta-analyses.[22] For example, this panel suggested that EPA develop criteria for selecting studies for inclusion in these analyses and indicated the need for changes in the statistical approaches used.

Many of these reviews also discuss the differences between the scenarios studied and the scenarios addressed by EPA regulations, which differ in several important respects (EPA 2000b,

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[20] If simply inflated to 2007 dollars (using the CPI-U), this range from the meta-analyses becomes $1.2 million to $12.5 million with a mean of $6.9 million.

[21] In recent analyses of drinking water rules, the range of VSL estimates from the 26 studies are reported in 2003 dollars after adjustment for both inflation and income elasticity (see EPA 2005a, Appendix F.1 for derivation). If these income and inflation-adjusted estimates are then further inflated to 2007 dollars (without additional adjustment for income growth), the range becomes $1.4 million to $20.2 million with a mean of $8.8 million. As noted earlier, if the range from the 26 estimates is instead simply inflated to 2007 dollars (using the CPI-U) without the income adjustment, the range becomes $1.0 million to $21.4 million, with a mean of $7.6 million.

[22] EPA completed or commissioned a number of papers to support this review, which was conducted in part to support revisions to its *Guidelines for Preparing Economic Analysis* (2000a). These papers include a review of recent VSL studies and meta-analyses (Dockins et al. 2004). EPA also funded research on the robustness of estimates from wage-risk and contingent valuation studies (Black, Galdo, and Liu 2003, Alberini 2004), as well as from studies of averting behavior (i.e., measures that individuals undertake to avoid or mitigate risks, such as the use of seat belts) (Blomquist 2004). In addition, EPA convened a group of statisticians to address the use of meta-analysis (EPA 2006b) and conducted a review of the literature on the relationship between the VSL and life expectancy (Dockins et al. 2006).

IEc 2001, Dockins et al. 2006). For example, the 26 studies focus largely on the risks of fatal accidents affecting workers who are middle-aged on average, while EPA's policies affect the risks of fatal illnesses that may be spread more widely throughout the population or concentrated in younger or older age groups. In addition, the affected populations may differ in terms of income, health status, or other characteristics. The health risks may also vary in terms of timing or duration, in their voluntariness or controllability, and in the extent to which they are dreaded.

Because only limited data are available on the effects of these population and risk characteristics, EPA discusses most of them qualitatively rather than adapting its VSL estimates, consistent with the advice of its advisory panels. (These adjustments are discussed in more detail in Chapter 4.) EPA has made quantitative adjustments to its base estimates for income growth and for any delays in the incidence of risk reductions (often referred to as cessation lags) in most regulatory analyses; adjustments for other factors (in either the base case or sensitivity analysis) have been made in only a few cases. For example, some analyses of drinking water rules have included the averted medical costs associated with a reduction in mortality risks (e.g., EPA 2005a), consistent with the advice from one advisory group (Cropper et al. 2001). With regard to age adjustments, the positions of EPA and its advisory panels have changed over time; EPA has discontinued its use of VSLY or other VSL age adjustments in recent analyses.

EPA is now revising its guidelines for economic analysis, and has asked the Environmental Economics Advisory Committee of its Science Advisory Board to review its proposed approach for estimating the VSL. The Committee is expected to initiate this review in late 2008.

2.3 DOT's Approach

In comparison to EPA, DOT promulgates fewer economically significant rules that involve the valuation of mortality risks. Most of these rules are developed by NHTSA, which relies on DOT-wide guidance for its base VSL estimates. This guidance was updated in February 2008.

Previously, DOT recommended the use of a $3 million VSL, noting that this value is imprecise and should be used as "a guide for thoughtful decision-making" (DOT 1993, DOT 2002, p. 1). That estimate was based largely on research conducted by Miller (1990), with adjustments for inflation and newer studies. Miller's estimates varied from those used by EPA (which were derived from Viscusi's 1992 and 1993 work) because he applied different criteria to determine which studies to include and adjusted the results to address certain of their limitations.

In recent regulatory assessments, NHTSA included sensitivity analyses that applied higher values. For example, for its electronic stability control systems rule, NHTSA included a probabilistic analysis that used a normally distributed range of VSL estimates from $1 million to $10 million, with a mean of $5.5 million (NHTSA 2007). As the source of this range, NHTSA cited two recent meta-analyses and a new wage-risk study (Mrozek and Taylor 2002, Viscusi and Aldy 2003, and Viscusi 2004). The range is also consistent with the range in OMB's Circular A-4 guidance (OMB 2003).

The new DOT guidance (DOT 2008) also recommends values within the range noted in OMB Circular A-4. DOT requires a best VSL estimate of $5.8 million, with sensitivity analyses using estimates of $3.2 million and $8.4 million (2007 dollars). When probabilistic analysis is conducted, DOT suggests that analysts use distributions restricted to positive values (such as the lognormal or Weibull), rather than the normal distribution (which can include negative values), with a standard deviation of $2.6 million.

This new guidance is based on a simple average of the best estimates from five recent studies, including four meta-analyses and one wage-risk study, adjusted for inflation and income growth over time.[23] Three of these studies were introduced in the Section 2.2 discussion of EPA practices: the meta-analyses by Mrozek and Taylor (2002), Viscusi and Aldy (2003), and Kochi et al. (2006). In addition, DOT includes a meta-analysis by Miller (2000), which considered 39 U.S. studies, 30 of which were wage-risk studies. DOT relies on a best estimate of $3.7 million (1995 dollars) from Miller's regression model results . The other study cited by DOT is Viscusi (2004), a wage-risk study that reports a mean VSL of $5.0 million (2000 dollars). DOT's estimates from each study, adjusted to 2007 dollars, are provided in Exhibit 2.2 below. These studies are discussed in more detail in Chapter 3.

Exhibit 2.2

VSL ESTIMATES USED IN DOT GUIDANCE
(2007 dollars)

Study[a]	DOT VSL Estimate[b]
Mrozek and Taylor (2002)	$2.6 million
Miller (2000)	$5.2 million
Viscusi (2004)	$6.1 million
Kochi et al. (2006)	$6.6 million
Viscusi and Aldy (2003)	$8.5 million

Source: DOT 2008, p. 4.
Notes:
a. Dates in table represent date of journal publication. DOT references earlier working papers for some of these studies.
b. Best estimates, adjusted for inflation and income growth, as determined by DOT. See Chapter 3 for more information on the estimates provided in each study.

In contrast to EPA, NHTSA primarily addresses injury-related accidental deaths rather than deaths from illness. Hence the scenarios it assesses are in some respects more similar to the scenarios addressed by most of the available VSL studies. NHTSA does not, however, adjust its values for remaining scenario differences (other than changes in real income over time), instead adjusting them to reflect changes in workplace and household productivity and to add costs such as those related to medical treatment, emergency services, insurance administration, workplace disruption, and litigation (Blincoe et al. 2002). Recent analyses (e.g., NHTSA 2007) that rely on DOT's older guidance indicate that the net effects of these changes lead to a value of $3.8

[23] DOT excluded two other meta-analyses, Bowland and Beghin (2001) and Liu, Hammitt, and Liu (1997), because they focus primarily on countries other than the U.S.

million per fatality (2005 dollars); i.e., a net increase in the base estimate (of $3.0 million) of 27 percent.

The new DOT guidance supports continuation of its current practices for these types of adjustments to the VSL estimates, recommending the addition of estimated economic losses "including property damage, traffic delays, lost productivity, and the costs of police, investigation, medical, legal, and insurance services" (DOT 2008, p. 6). In making these adjustments, DOT notes that it disaggregates the VSL into two components: after-tax earnings (or net productivity losses) and the value of pain, suffering, and lost quality of life.[24] The DOT guidance does not support adjustments for different population subgroups, indicating that the same VSL should be applied to all individuals, "regardless of age, location, income, or mode of travel" (DOT 2008, p. 8).

2.4 Approaches Used by Other Agencies

Two other agencies subject to OMB review (FDA and OSHA) have promulgated more than one economically significant final rule in recent years that included quantified estimates of mortality risk reductions. These agencies generally expend less effort than EPA on VSL-related research and expert review, due at least in part to the fact that they promulgate substantially fewer major rules that include quantified mortality risk reductions. In addition, CBP has used VSL estimates in its breakeven analyses, which assess the reduction in the likelihood of terrorist attacks that would be needed for the benefits of the rule to equal or exceed its costs.

FDA has not developed formal internal guidance for its economic analyses, and cites selected VSL literature reviews and meta-analyses (e.g., Fisher et al. 1989, Viscusi 1992, Viscusi and Aldy 2003) as the sources of its estimates. It generally relies on a VSL estimate of $5 million (without specifying a dollar year), roughly in the middle of the $1 million to $10 million range cited in Circular A-4 (OMB 2003). FDA also occasionally reports alternative benefit estimates using higher or lower values (see, for example, FDA 2003, FDA 2004, FDA 2005).

FDA occasionally adjusts its VSL estimates for certain scenario differences. In some cases it has addressed latency (e.g., in its trans-fat rule, FDA 2003), and it added the cost of cancer treatment ($25,000) and an adjustment for fear and anxiety ($5,000) to the VSL for its X-ray rule (FDA 2005).[25] A few FDA analyses have presented alternative estimates using VSLY as

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[24] DOT's approach to disaggregating the VSL into these two components is not widely accepted or used. See also Section 4.2.1 for more discussion of the treatment of morbidity prior to death. In regulatory analyses, Federal agencies generally distinguish between fatal risks (where a death results prematurely from an illness or injury associated with the regulated hazard) and nonfatal risks (where death ultimately results from causes not associated with the hazard).

[25] FDA also made an adjustment for temporary fear and anxiety in its 1997 mammography rule and in its 2006 medical gloves rule (FDA 1997, FDA 2006). The adjustment was calculated as follows. Based on research on factors that influence an individual's health-related quality of life, the analysts assume that adverse psychological reactions reduce well-being by 8 percent. Furthermore, they assume that worries about one's own health contribute about one-sixth to triggering a major stressful episode. Combining these results suggests that worries about one's own health contribute 1.3 percent (8 percent x 1/6) to one's overall sense of well-being. Based on a VSLY of $373,000, they calculate that the value of averting these

well as VSL estimates (e.g., FDA 2003). Thus although FDA's base estimate seems similar to the VSL estimates used by EPA, ultimately the values will differ because of the inflation, income growth, and other adjustments that EPA includes in its analyses.

OSHA rules vary in terms of whether they address mortality risks from accidents or from illnesses, and the agency has changed its approach to valuing risk reductions over time. In its assessment of a rule governing safety standards for steel erection (OSHA 2001), OSHA did not assign a monetary value to the predicted reductions in mortality risks. More recently, in assessing a rule that addressed lung cancer and other risks from exposure to hexavalent chromium (OSHA 2006), OSHA adopted an approach similar to EPA's. OSHA used a base VSL of $6.9 million (2003 dollars) then adjusted it for latency and for changes in real income over time, and added the value of averted medical costs.

As noted in the introductory chapter of this report, it is difficult for CBP to estimate the benefits of its rules because of the challenges inherent in quantifying the associated reductions in terrorism risks. For its recently proposed Western Hemisphere Travel Initiative (WHTI) rule governing documentation requirements for international land travelers, CBP instead relied on a breakeven analysis conducted by researchers from RAND's Center for Terrorism Risk Management Policy (Latourrette and Willis 2007, IEc 2007a). This analysis assessed the reduction in terrorism risk that would be needed for the benefits of the rule to be equal to or greater than its costs.

The breakeven analysis used Risk Management Solutions' (RMS') Probabilistic Terrorism Model, which predicts the risks from numerous different attack scenarios. In the modeling (reported as 2005 dollars), fatalities were valued using two alternative VSL estimates, $3 million and $6 million, which were described as reflecting (respectively) the values typically used by DOT and EPA at that time.

2.5 Summary and Conclusions

As discussed above, current OMB guidance suggests that VSL estimates range from about $1 million to $10 million (without specifying a dollar year), but allows agencies to exercise some discretion in determining the estimates most appropriate for their rulemakings. Agencies responsible for economically significant regulations generally use values that fall within this range, although each uses somewhat different best estimates. Exhibit 2.3 provides examples of the values used in recent regulatory analyses.

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worries over the course of a year would be about $5,000 (1.3 percent x $373,000). (See FDA 2005, p. 34021). Depending on the rule, FDA then divides this estimate by the number of days or months in a year to reflect the expected duration of the worrisome episode.

Exhibit 2.3

EXAMPLES OF VSL ESTIMATES USED IN RECENT REGULATORY ANALYSES

Agency	Regulation	Mean Base VSL Estimate (Range and Dollar Year)	Adjustments For Scenario Differences[a]
EPA, Office of Air and Radiation	National Ambient Air Quality Standards for Particle Pollution (EPA 2006a)	$5.5 million ($1.0 million – $10 million,[b] 1999 dollars)	• Income growth over time • Cessation lag
EPA, Office of Ground Water and Drinking Water	Stage 2 Disinfectants and Disinfection Byproducts Rule (EPA 2005a)	$7.8 million ($1.2 million – $17.9 million,[c] 2003 dollars)	• Income growth over time • Cessation lag • Medical costs prior to death
HHS, Food and Drug Administration	Performance Standard for Diagnostic X-Ray Systems (FDA 2005)	$5 million (none, no dollar year reported)	• Latency • Medical costs prior to death • Psychological dread
DOT, National Highway Traffic Safety Administration[d]	Electronic Stability Control Systems (NHTSA 2007)	$3 million ($1.0 million – $10 million,[e] 2005 dollars)	• Productivity losses • Medical treatment, emergency services, insurance administration, workplace disruption, and litigation costs
DOL, Occupational Safety and Health Administration	Occupational Exposure to Hexavalent Chromium (OSHA 2006)	$6.9 million (none, 2003 dollars)	• Income growth over time • Latency • Medical costs prior to death
DHS, Customs and Border Protection	Western Hemisphere Travel Initiative Rule For International Land Travelers (IEc 2007a)[f]	$3 million, $6 million (2005 dollars)	• None

Notes:
a. Column includes quantitative adjustments; other differences are often discussed in text. See Chapter 4 for more information on these adjustments.
b. Normal distribution, range described as 95 percent confidence interval.
c. Weibull distribution, range described as 5th and 95th percentiles, includes adjustment for real income growth.
d. This rule was promulgated before the 2008 update of DOT's VSL guidance.
e. Normal distribution.
f. Breakeven analysis, values based on EPA and DOT approaches.

The base VSL estimates in the exhibit are derived from literature reviews conducted in the early 1990s, as well as from more recent meta-analyses that provide estimates which tend to be within the same range. A recent expert review of the approaches used in these meta-analyses (sponsored by EPA) recommends a number of improvements, but it is unclear how these changes might affect the resulting values.

EPA currently adjusts its base VSL estimates to reflect income growth over time and any time lags between the reduction in exposure and the reduction in incidence, and in some cases adds the value of medical costs incurred prior to death. (The rationale and approach for these adjustments is discussed in more detail in Chapter 4). OSHA followed the same practices in a recent rule. In contrast, FDA adjusts for these differences infrequently. Under the new (2008) DOT guidance, NHTSA will be adjusting its estimates for income growth over time, and adds other expenditures to its VSL estimates. Thus the estimates ultimately applied in each analysis may differ from the base estimates reported in the exhibit due to differing approaches to these adjustments. In addition, the agencies vary in the extent to which they update their estimates for inflation.

As discussed in more detail in Chapter 4, available empirical evidence as well as economic theory suggest that the VSL may differ depending on the characteristics of the affected population and the risks averted. Thus the use of different VSL estimates may be justified in cases where agencies are addressing different populations or types of risk, as noted in OMB's guidance. However, available research does not provide an adequate basis to develop quantitative adjustments for most of these differences. The variation in values across agencies reflects different interpretations of the literature rather than investigation of the values most relevant to the particular regulatory scenarios, due at least in part to the gaps in the research base.

3.0 ALTERNATIVE SOURCES FOR BASE VSL ESTIMATES

As described in the prior chapter, Federal agencies generally follow a two-step process when valuing mortality risk reductions. First, they develop base estimates of the value per statistical life (VSL), usually derived from the results across a number of different studies. Then, they adjust these estimates to the extent possible to better reflect the characteristics of the populations and risks affected by their regulations. This chapter discusses the options for the first step in more detail.

One simple approach for deriving base estimates involves calculating the mean value across a range of studies. For example, in the early 1990s, the U.S. Environmental Protection Agency (EPA) identified a group of suitable studies based on a literature review conducted by Viscusi (1992, 1993), selected "best" estimates from these studies, then calculated the mean of these best estimates (e.g., EPA 1997, IEc 2001). EPA also used a distribution based on the best estimates from each study in uncertainty analysis. More recently, EPA and other agencies have begun citing the VSL meta-analyses to support their estimates. These meta-analyses use statistical techniques to combine results across studies and to examine the factors that influence the variation in the results. For example, the U.S. Department of Transportation (DOT) calculated its mean VSL from the best estimates reported across four meta-analyses and one individual study (DOT 2008).

The meta-analyses used to support the VSL estimates applied by Federal agencies were introduced in Chapter 2 and are discussed in more detail below. These analyses were conducted before many newer VSL studies were published, and rely largely on studies that use relatively old data and statistical methods and hence may not reflect current conditions or best practices. Thus a key question is whether relying on newer studies may be more appropriate; this chapter also describes recent VSL studies selected to illustrate current standards for conducting these types of research.

The following sections first consider the available meta-analyses, then discuss selected recent studies, and concluding with a summary of these options for developing base estimates. Chapter 4 next discusses possible adjustments to these estimates for scenario differences, and Chapter 5 provides specific recommendations for using this research to value mortality risks in analyses of homeland security rules.

3.1 VSL Meta-Analyses

As indicated in Chapter 2, Federal agencies often focus on four meta-analyses as suitable for use in regulatory analyses, although the particular analyses cited vary by agency. Meta-analysis is an approach for synthesizing the findings from several independent studies and examining the variation in the results. The steps in a meta-analysis generally include: defining the outcome of interest, searching the literature for studies that address this outcome, developing and applying criteria to select studies for inclusion in the analysis, using statistical methods (such as meta-regression or Bayesian pooling models) to synthesize the studies, and reporting the results.

When applied in the VSL context, several issues arise in conducting meta-analyses.[26] Many of these concerns relate to defining the outcome of interest: while the available meta-analyses generally report a best estimate of the VSL as well as a range (e.g., a 95 percent confidence interval or mean results from different models), the selection criteria and analytic methods are not necessarily tailored to developing best estimates for the particular populations or risks addressed by regulatory analyses. Researchers are often more interested in exploring factors that may explain the variation in the estimates, such as the effects of income differences or alternative regression specifications, data sets, and/or stated vs. revealed preference methods.

In addition, experts disagree on whether and how results from different types of studies (wage-risk vs. contingent valuation) should be combined, since to some extent they are measuring different outcomes (the trade-off between job-related income and risk vs. individual willingness to pay (WTP) for a scenario defined by the study). The most frequently cited VSL meta-analyses focus primarily on wage-risk studies (with one exception as discussed below); the contingent valuation research has not received as much attention. The meta-analyses also include studies from a number of different countries, raising questions about whether these estimates should be considered when estimating the VSL for the U.S. population.

Another set of issues relates to the criteria used to select studies. Researchers vary in the extent to which they restrict themselves to studies with certain characteristics, as well as in the specific criteria they apply. The processes followed to identify and select relevant studies are not always clearly or fully described. In addition, bias may arise if the meta-analysis excludes results that are not statistically significant, which may occur either because the research was never published or because the published article only included the significant results.

Finally, there are a number of issues related to the statistical analysis. Examples of these concerns relate to whether and how to incorporate estimates that are not fully independent (e.g., because a study presents multiple models based on the same data or because more than one study uses the same data set), deciding which variables to include and how to define them (e.g., whether to include nonfatal risk measures and whether to define variables in linear or log form), and determining which types of statistical methods or models to use.

The key meta-analyses currently used to support Federal regulatory assessments are listed in Exhibit 3.1 in order of publication, and are described in more detail below. The exhibit also reports the estimates highlighted by the authors, focusing on the results that include the U.S. wage-risk studies only for comparability. (This section focuses on describing the studies; see Chapter 2 for information on how the estimates from these studies are currently used in regulatory analyses.)

[26] For more information on these issues, see EPA (2006b), Cropper et al. (2007), and Aldy (2008) as well as the individual studies discussed in this section.

Exhibit 3.1 RECENT VSL META-ANALYSES[a]			
Study	**Studies Included (publication dates)[c]**	**"Best" VSL Estimate[b]**	
		As Reported (dollar year)[d]	**Inflated to 2007 Dollars[e]**
Miller (2000)	U.S. wage-risk studies (1974 – 1990)	$3.7 million (1995 dollars)	$5.0 million
Mrozek and Taylor (2002)	U.S. wage-risk studies (1974 – 1995)	$1.5 million to $2.5 million (1998 dollars)	$1.9 million to $3.2 million
Viscusi and Aldy (2003)	U.S. wage-risk studies (1974-2000)	$5.5 million to $7.6 million (2000 dollars)	$6.6 million to $9.2 million
Kochi, Hubbell and Kramer (2006)	U.S wage-risk studies (1974-2002)	$8.9 million (2000 dollars)	$10.7 million

Sources: Aldy (2008) and the individual studies cited.
Notes:
a. Exhibit provides estimates for U.S. studies only; each meta-analysis also provides estimates for other countries.
b. The estimates used by Federal agencies vary from those presented in the exhibit in some cases, and are described in Chapter 2.
c. Includes the subset of studies used to developed the estimates highlighted by the authors and presented in the subsequent column; Kochi et al. (2006) also include contingent valuation studies in some of their models.
d. Mean or median estimate(s) for the U.S., highlighted by the authors in their abstract or discussion of alternative models.
e. Adjusted for inflation using the Consumer Price Index - All Urban Consumers (CPI-U, http://www.bls.gov/CPI/). Not adjusted for income growth over time.

Miller (2000): This meta-analysis was designed to support the transfer of VSL estimates across countries, by developing regression models that take into account the variation in national income. It includes VSL estimates from 68 studies conducted in 13 countries; for the U.S., the estimates were restricted to 30 derived from the wage-risk studies reviewed in Miller (1990). The U.S. studies were published between 1974 and 1990, relying on wage data collected between 1940 and 1982. When averaged across these 30 U.S. estimates, Miller reports a VSL of $3.5 million (1995 dollars).

Miller experiments with different approaches to measuring income (e.g., as gross domestic product per capita, adjusted for purchasing power parity) and to controlling for other factors (e.g., whether the study includes mortality from all causes or only job-related risks; whether it includes workers' occupations as well as the industry in which they are employed). In 1995 dollars, his preferred regression model provides a best estimate of $3.7 million for the U.S.; the alternative models result in estimates ranging from $3.3 million to $4.5 million.

Mrozek and Taylor (2002):[27] In this article, the researchers first explore the effects of different study characteristics on the VSL, then adjust the results of each study to reflect their "best practice" assumptions. They begin by estimating the VSL based on four models that vary in which studies they incorporate. Depending on the model, the researchers include up to 203 observations from 33 wage-risk studies published between 1974 and 1997, including 91 U.S.

[27] This article was accompanied by commentary by Hammitt (2002b) and Krupnick (2002).

estimates from 25 studies published between 1974 and 1995. The models all include a large number of explanatory variables that describe the data sources and methodology used in each study as well as other factors expected to influence the VSL. Across the four models, the mean VSL ranges from $5.6 million to $7.7 million (1998 dollars); the higher estimate results when non-U.S. estimates are excluded.

The researchers then use their findings to adjust the VSL estimates to better reflect their "best practice" assumptions. They focus on estimating the VSL from U.S. studies, excluding those focused on high risk occupations (i.e., more than 5 deaths per 10,000 workers) or using risk data (from the Society of Actuaries) that reflect mortality from all causes rather than only job-related accidents. Rather than using best practices as criteria for selecting studies, they predict the VSL based on their estimates of the effects of best practices. For example, if a study did not control for job characteristics, they estimate the effects of these characteristics based on the results for those studies that included these variables.

They found that the effects of substituting these best practice assumptions can be significant. For example, controlling for inter-industry differences substantially reduced the VSL. Their best practice estimates are well below those found in other studies, ranging from $1.5 million to $2.5 million.

Viscusi and Aldy (2003): This frequently-cited, comprehensive study provides a detailed discussion of the theoretical and empirical issues that arise when estimating the VSL and applying it in policy analyses. It discusses over 60 studies from 10 countries that primarily address job-related mortality risks, but also includes some that address the risks of disease or nonfatal injury. The article also considers studies that assess trade-offs outside of the labor market, such as the use of seat belts or smoke detectors. The researchers analyze a number of related issues, including the effects of union membership, age, and income on the VSL.

For the U.S., the authors focus on 30 labor market studies published between 1974 and 2000, which rely on wage and risk data collected between 1960 and 1988. Across these studies, the median VSL is about $6.7 million (2000 dollars). Depending on the model used, the mean VSL predicted from the U.S. studies ranges from $5.5 million to $7.6 million (Table 8, p. 42). Across the different models, the lowest value for the 95 percent confidence interval is $3.0 million and the highest is $19.4 million.

Kochi, Hubbell, and Kramer (2006): In this study, the researchers combine estimates from selected VSL studies using an empirical Bayes approach with two-stage pooling. This approach is designed to take into account the variance in the estimates, placing more weight on those measured with greater precision. The authors select 31 wage-risk studies and 14 contingent valuation studies to include in their analyses, although some are dropped from particular model specifications due to problems with the reported data. The studies were conducted in a range of high income countries; the authors also provide estimates based solely on the U.S. wage-risk studies.

If a simple mean is calculated from all of the estimates provided in all of the studies, it equals $10.8 million (2000 dollars). Once assessed using the empirical Bayes approach to control for the effects of different variables as well as to account for the precision of the estimates, this mean drops to $5.4 million with a standard deviation of $2.4 million (Table 2, p. 397). If only the U.S. wage-risk studies are included, the mean increases to $8.9 million with a standard deviation of $5.3 million. The researchers find that the pooled estimates are affected by the valuation method used (wage-risk vs. contingent valuation), the study location (U.S. vs. other countries), and the union status of the sample, but not by the source of the risk data nor the inclusion of nonfatal injury risks.

In summary, the authors' best U.S. estimates from these four meta-analyses cover a broad range, from $1.9 million to $10.7 million when inflated to 2007 dollars. Each study also provides measures of uncertainty, consideration of which broadens this range. Review of these meta-analyses suggest that they are dominated by studies that rely on relatively old data and are unlikely to adhere to currently accepted best practices.

For example, starting in 1992, BLS began collecting fatality risk data through the Census of Fatal Occupational Injuries (CFOI) to address some of the limitations of the older BLS and NIOSH data sets (discussed in Viscusi and Aldy 2003). This census was designed to address the limitations of earlier sampling strategies that appeared to result in some systematic biases, and indicates that fatality risk levels are higher than previously reported. However, most of the studies used in the meta-analyses listed in Exhibit 3.1 were completed before the CFOI data became available. In addition, reliance on older wage data will not reflect changes in the wage-risk relationship over time that may result from changes in the labor market and workplace conditions as well as in employers' and workers' preferences.[28]

Recent expert review of the VSL meta-analyses also indicates a need to improve the methods used. EPA's meta-analysis work group noted that, "whereas meta-analysis is a reasonable tool for the analysis of the literature on VSL, the existing meta-analyses all suffer from weaknesses in execution that preclude relying on any of them as a source of a final VSL estimate" (EPA 2006b, p. 25).[29] Building on that report, an EPA Science Advisory Board panel indicated that researchers should establish criteria for selecting well-executed studies that are applicable to the population of concern (Cropper et al. 2007). Both panels recommended improvements in the statistical techniques used and in the reporting of the data, methods, and results.

3.2 Recent VSL Studies

As discussed in more detail in Chapter 5, we conducted a workshop with three leading VSL experts to support this report: Dr. Joseph E. Aldy (Resources for the Future), Dr. James K. Hammitt (Harvard University), and Dr. Alan Krupnick (Resources for the Future). As part of that workshop, the experts identified recent studies that they believed illustrated current best practices (Aldy 2008). This section summarizes those studies, which include two wage-risk studies and

[28] As noted earlier, wage-risk studies reflect the equilibrium between workers' demand for wages across jobs with differing characteristics and employers' willingness to supply jobs at these wage rates.
[29] This review focused on Mzorek and Taylor (2002), Viscusi and Aldy (2003), and Kochi et al. (2006) and did not explicitly address Miller (2000); however, its conclusions are also applicable to this earlier analysis, which relies on older U.S. studies.

three contingent valuation or conjoint surveys. These studies are listed in Exhibit 3.2 below, along with the U.S. estimates highlighted by the authors.

Exhibit 3.2

RECENT VSL STUDIES

Study	Population Assessed (year data collected)	Risks Assessed	"Best" VSL Estimate: As Reported (dollar year)[a]	"Best" VSL Estimate: Inflated to 2007 Dollars[b]
Wage-Risk Studies				
Viscusi (2004)	U.S. workers (1992-1997)	Job-related	\$4.7 million (1997 dollars)	\$6.1 million
Aldy and Viscusi (forthcoming)	U.S. workers (1992-2000)	Job-related	\$4.5 million (1997 dollars)	\$5.8 million
Contingent Valuation and Conjoint Studies				
Corso et al. (2001)	U.S. residents (1998-1999)	Auto safety (air bags)	\$3.0 million to \$3.3 million (1999 dollars)	\$3.7 million to \$4.1 million
Alberini et al. (2004)	U.S. residents (≥age 40) (2000)	Unspecified product	\$1.5 million to \$4.8 million (2000 dollars)	\$1.8 million to \$5.8 million
DeShazo and Cameron (2004)	U.S. residents (2002)	Statistical illness profiles	\$3.5 million (2002 dollars)	\$4.0 million

Sources: Aldy (2008) and the individual studies cited.
Notes:
a. Mean or median estimate(s) for the U.S., highlighted by the authors in the abstract or discussion of alternative models.
b. Adjusted for inflation using the CPI-U (http://www.bls.gov/CPI/). Not adjusted for income growth over time.

Viscusi (2004): This study examines the relationship between wages and job-related risks, based on data and model specifications that incorporate several improvements over earlier research. The data used are more recent than those applied in most studies included in the meta-analyses discussed above, including 1992-1997 CFOI data on job-related risks and 1997 Current Population Survey (CPS) data on wages. As noted earlier, the CFOI reflects a number of enhancements over older sources of fatality risk data. It is a census rather than a sample, and is based on review of a more comprehensive set of related records (including death certificates, worker's compensation reports, etc.) and involves additional confirmation of the data.

In addition, this study addresses a number of problems with how the job risk variable was defined in earlier studies. Rather than solely considering risks by industry or by occupation, it considers the combined effects of both industry and occupation. This approach allows more accurate estimation of the relationship between wages and risks, and better captures the effects of nonfatal job-related risks and the workers' compensation replacement rate on the estimates. In particular, because nonfatal and fatal risks are generally correlated, excluding nonfatal risks from the regression model can bias the VSL estimate upwards. Controlling for nonfatal risks also avoids the potential for double-counting, if the resulting VSL estimate is used in a regulatory analysis that separately accounts for the value of nonfatal risk reductions.

For the full sample, controlling for nonfatal risks and workers' compensation replacement, Viscusi's best estimate is a mean VSL of $4.7 million (1997 dollars).[30] Alternative mean estimates range from $2.5 million to $10 million depending on whether both industry and occupation are included in estimating the risk variable, on how the wage variable is defined (as wages or as the natural log of wages), and on whether the risk data is from 1997 only or averaged across 1992 to 1997. In addition, the author explores variation in the VSL related to gender and to the inclusion of blue vs. white collar workers, as well as the effects of alternative model specifications.

Aldy and Viscusi (forthcoming):[31] This forthcoming wage-risk study is primarily focused on examining the relationship between age and the VSL (discussed in more detail in Chapter 4), but also provides information on the mean VSL (without age adjustment). If not allowed to vary by age, the researchers find that the mean VSL is $4.5 million (1997 dollars) using the standard hedonic wage approach, building on the framework applied in the study described above.

The authors also use eight years of CFOI data (from 1992-2000) to construct a fatality risk measure that varies by age and by industry, as well as data from the CPS. Once age is considered, they find that the VSL follows an inverse-U shaped pattern, peaking in middle age.

Corso, Hammitt, and Graham (2001): This contingent valuation survey was designed to investigate the effects of different visual aids on individual WTP for mortality risk reductions. The survey asked respondents to indicate their WTP for side impact air bags that would reduce the likelihood of fatality from automobile crashes. Baseline fatality risks were either 2.0/10,000 or 2.5/10,000 per year; in both survey variants, airbags were described as reducing the risk to 1.5/10,000. The survey was administered in 1998-1999 to a random sample of U.S. residents (age 18 and older) through a combination of phone and mail contacts. Completed surveys were provided by 1,104 respondents.

As introduced in Section 1.2, theory suggests that WTP should be sensitive to the size of the risk reduction: small changes in the magnitude of the risk should result in nearly proportional changes in the magnitude of individual WTP.[32] However, many contingent valuation surveys have found relationships that are far from proportional. Corso et al. hypothesize that these results may reflect problems with how the risk change was communicated. They experiment with different visual aids, and find that presenting the risk change as an array of dots leads to the WTP estimates that are most consistent with theory. Depending on the size of the risk reduction (1.0/10,000 or 0.5/10,000), the VSL estimated using the dot array was $3.0 million to $3.3 million (1999 dollars, Table 3, p. 175).

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[30] See Appendix A for information on the 95 percent confidence interval for this estimate, developed by Dr. Joseph E. Aldy.

[31] This discussion is based on a draft provided by Dr. Aldy, dated April 23, 2007.

[32] As noted in Section 1.2, the relationship may be concave rather than linear, with WTP for each incremental risk reduction decreasing by some amount. This relationship can result in somewhat larger VSL estimates for smaller incremental risk reductions. (As discussed earlier, for an individual, the VSL is equivalent to WTP divided by the risk change.) However, the relationship between WTP and the size of the risk change should be close-to-proportional when the risk change is small, with minimal affect on the VSL.

Alberini, Cropper, Krupnick, and Simon (2004): In this study, the researchers explored the effects of age and health status on the VSL. They conducted two contingent valuation surveys, one in Ontario, Canada, and one in the U.S. Both samples were restricted to individuals age 40 and above. Respondents were given the baseline risk of fatality over the subsequent 10 years for someone of their age and gender, then asked whether they would be willing to purchase a product that would reduce this 10-year risk by 1/1,000 or 5/1,000 (1/10,000 or 5/10,000 annually). The survey used grids with colored squares to communicate the magnitude of the risk changes.

For the U.S. sample, the survey was administered via the Internet (using Knowledge Networks) to a random sample of residents, resulting in 1,200 completed responses. The VSLs estimated from the mean U.S. WTP estimates were $1.5 million for a 5/10,000 annual risk change, and $4.8 million for a 1/10,000 risk change (2000 dollars, Table 7, p. 784). The median responses were lower: $0.7 million and $1.1 million respectively. Based on validity testing, the authors expressed more confidence in the results for the 5/10,000 risk change.

The authors found that (as expected) the number of respondents agreeing to the payment declined as the dollar amount increased, and that respondents were willing to pay more for larger risk reductions. However, they found that WTP was not proportional to the size of the risk change. For age, their results suggested that individuals above age 70 were willing to pay about 20 percent less than younger individuals for an equivalent risk reduction. The effect of age was not statistically significant for the U.S. sample; however, it was significant for the Canadian sample. In addition, the researchers found that impaired health did not affect WTP. (See Chapter 4 for more discussion of the effects of age and health status on the VSL.)

DeShazo and Cameron (2004): This working paper presents the results of an ambitious and innovative effort to develop WTP estimates for lifetime profiles that include the likelihood of various types of morbidity and mortality at different ages. The authors label the outcome measure as the value of statistical illness (VSI), rather than the VSL, due to the inclusion of nonfatal health impacts. The profiles are presented as a conjoint choice experiment, based on 12 different illnesses described using up to 11 attributes. Respondents are told that new programs are being developed that will reduce the risks of these illnesses; the programs involve diagnostic testing, drug therapies, and lifestyle changes. Respondents are then asked to choose among pairs of programs focused on different illness profiles. The survey was conducted via the Internet (using Knowledge Networks) to a random sample of U.S. residents, with 1,619 usable responses.

The authors estimated the VSI for different ages and illness profiles, considering the effects of current age and the age at which a health effect would occur. They experimented with different model specifications and faced a number of challenges, such as negative predicted VSIs, insignificant findings, and very wide confidence intervals. For comparison to the VSL estimates from wage-risk studies, the authors focus on the VSI for sudden death at age 45. Under their preferred model, they find that this VSI is $3.5 million (2002 dollars).

In summary, the mean or best VSL estimates from recent studies range from $1.8 million to $6.1 million when inflated to 2007 dollars. This range reflects the estimates highlighted by the authors; all of the studies provide alternative estimates that result from different model specifications and provide information on uncertainty in the estimates. The results from the two wage-risk studies are very similar (if not adjusted for age), which is not surprising given that they build on much of the same data and methods. The range of estimates from the contingent valuation and conjoint analyses is wider, reflecting the different approaches used and the variation in the types of risks assessed. These latter estimates reflect some of the challenges often faced in stated preference studies. For example, the estimates from Alberini et al. (2004) are not proportional to the risk reduction, and the estimates from the DeShazo and Cameron (2004) study appear highly uncertain.

3.3 Summary and Conclusions

Federal agencies often cite some or all of four recent meta-analyses as the source of their VSL estimates. These meta-analyses synthesize the findings from several independent studies, but vary in which studies they include and in the methods they use to analyze the results. The U.S. wage-risk VSL estimates from these analyses range from $1.9 million to $10.7 million when inflated to 2007 dollars. Review of these meta-analyses indicates that they include many studies which rely on relatively old data and methods that may not adhere to currently accepted best practices. Recent expert panel recommendations also suggest that the approaches used are in need of improvement.

Newer studies provide U.S. VSL estimates ranging from $1.8 million to $6.1 million in 2007 dollars. Two recent wage-risk studies that rely on somewhat similar data and methods result in relatively comparable mean VSL estimates ($5.8 million and $6.1 million). The contingent valuation and conjoint surveys result in a wider range of estimates that are often lower than found in the wage-risk studies. However, these stated preference studies face several challenges, such as findings that indicate a lack of proportionality between changes in risk and changes in the VSL or that provide negative values for risk reductions.

4.0 ADJUSTMENTS FOR SCENARIO DIFFERENCES

As introduced earlier, studies of the value of statistical life (VSL) focus on scenarios that differ in some significant respects from the scenarios addressed by homeland security and other Federal regulations. Agencies have developed approaches to quantitatively adjust the VSL estimates for some of these differences; for others, the research base is limited or provides inconsistent results. While new studies are now being published that provide additional insights into these issues, they have not yet been thoroughly reviewed to determine their implications.

This chapter discusses these scenario differences, first summarizing those that have received the most attention in recent reviews and then discussing in more detail how the cause or source of the risk (i.e., terrorism rather than other hazards) may affect the VSL. Because of the importance of VSL estimates in analyses of environmental regulations, a significant proportion of the related research has been funded by the U.S. Environmental Protection Agency (EPA) and reflects the issues of concern in its analyses. Many of these issues, such as the age of the affected population, are of lesser concern in the context of anti-terrorism rules. In addition, a key issue for U.S. Customs and Border Protection (CBP) regulations (and for Department of Homeland Security (DHS) regulations more generally) – the effect of risk perception on valuation – has received only limited attention in these reviews. Mortality risks from terrorist acts may be valued differently than other, more commonly studied hazards, because they result from low probability but potentially catastrophic events that are likely to be viewed as relatively uncontrollable, involuntary, and unfamiliar as well as greatly feared.

The discussion that follows focuses largely on issues related to the application of VSL estimates from wage-risk studies to other scenarios, because these studies dominate the literature that Federal agencies currently use to value mortality risk reductions. The number of stated preference studies is increasing, however, and emerging studies may provide important additional information. For example, Krupnick (2007) identifies 35 recent stated preference studies, including two that are unpublished and 12 working papers. His review focuses on the relationship between age and VSL, but these and other new studies also provide data on other potentially significant scenario differences. As discussed in Chapter 5, additional review of the emerging research may be desirable.

This chapter first discusses scenario differences related to the population affected by the regulations (income, age, health status, background risks, and self-selection) and then discusses differences related to the nature of the risks themselves (latency and morbidity, and altruism) that are often considered in the context of environmental risks. The following section then explores in more detail another risk characteristic, the effects of how the risks are perceived, which may be particularly important in the homeland security context. For ease of presentation, the scenario differences are discussed individually. However, they are often inter-related, and effectively addressing these differences requires considering their correlation. The chapter concludes with a summary of the discussion. Chapter 5 then discusses the recommendations for applying these adjustments when valuing the mortality risks of homeland security rules.

4.1 Differences in Population Characteristics

Many homeland security initiatives are expected to avert a variety of different types of attacks, which in turn may affect individuals with a range of different characteristics. As discussed in Section 1.1, it is difficult to characterize the populations likely to be affected in detail. It appears that the mortality risk reductions associated with homeland security rules are likely to disproportionately accrue to workers in major urban areas, given the most probable terrorist targets. However, other locations and population groups may also be affected.

Previous reviews of VSL adjustments generally concentrate on environmental risks (e.g., EPA 2000b, IEc 2001), which often disproportionately affect older individuals who may be in poor health. As described in Chapter 2, Federal regulatory agencies rely largely on wage-risk studies when estimating the VSL. In contrast to the risks often addressed by EPA, these studies include only working-age individuals (predominately male), excluding those who are younger and older or whose health is too impaired for them to work. In addition, these studies are likely to reflect self-selection; i.e., individuals with below-average aversion to risk (and above average ability to avoid it) may be more likely to accept riskier jobs. In considering the conclusions of these prior reviews, a key concern is thus the extent to which the population affected by homeland security regulations is similar to the population affected by the environmental risks addressed by the reviews.

The following sections focus on five of these population characteristics: income, age, health status, background risks, and self-selection.[33] They discuss theoretical considerations and the available empirical research, the conclusions of related expert panel reviews, and the implications for homeland security regulations.

Adjusting VSL estimates to reflect differences in individual willingness to pay (WTP) across population subgroups is consistent with the underlying focus of benefit-cost analysis on individual preferences, consumer sovereignty, and economic efficiency.[34] However, these adjustments can be controversial due to concerns about the equitable treatment of different groups in policy decisions. For example, while research suggests that older individuals may have lower WTP for their own mortality risk reductions than younger individuals, using lower estimates has led to protests about perceived inequities. Thus, as discussed below, Federal

[33] As noted in Krupnick (2008), education, gender, race, and other characteristics may also affect the VSL.

[34] Benefit-cost analysis applies criteria developed by Kaldor and Hicks, which suggest that a project is desirable if it makes the winners better off by an amount large enough to compensate the losers (or alternatively, that a project should be rejected if the losers could compensate the winners not to pursue the policy). These criteria do not demand that actual compensation occur. (Economists often argue that equity is best dealt with by policies that directly address the distribution of income (e.g., through the tax system) rather than by regulations focused primarily on other goals.) Thus benefit-cost analysis focuses on net social welfare gains rather than on whether the distribution of the impacts is equitable, and equity is addressed separately in regulatory analyses.

agencies generally do not modify their VSL estimates to reflect differences in WTP across population subgroups, adjusting only for population-wide income growth over time.[35]

4.1.1 Adjustments for Income

Empirically, the effect of income on the VSL is clear and measurable: as income increases, WTP for risk reductions usually increases.[36] While this effect could be measured both cross-sectionally (across individuals or subpopulations) and longitudinally (over time), most relevant studies are cross-sectional.[37] However, using different VSL estimates for individuals with different incomes is controversial and can raise concerns about the equitable treatment of richer and poorer segments of the population in policy analysis. As a result, Federal agencies generally do not make cross-sectional adjustments in their VSL estimates.

Instead, some Federal agencies use cross-sectional data to estimate the longitudinal change in the VSL likely to occur as real per capita income changes over time. This adjustment involves estimating the percentage change in the VSL associated with a one percent change in income (i.e., its income elasticity). EPA often uses a distribution of income elasticity estimates with a mode of 0.40 and endpoints at 0.08 and 1.00 based on its 1999 review of the literature, and measures the change in income based on yearly estimates of real per capita Gross Domestic Product (GDP).[38] EPA typically first inflates the VSL estimates to a common base year (generally using the Consumer Price Index (CPI)), and then applies the adjustment for real income growth up to the point where the risk reductions occur.[39] The same estimates of income-adjusted VSL are then used for all members of the population affected by the rulemaking.

DOT's recent guidance (DOT 2008) uses a slightly different approach. DOT adjusts VSL estimates for both inflation and income growth from the dollar year reported in each underlying study to 2007 dollars. DOT uses the CPI to adjust for inflation and an income elasticity estimate of 0.55 based on Viscusi and Aldy (2003). It applies the elasticity estimate to the wages and salary component of the Employment Cost Index. The EPA and DOT approaches are summarized in Exhibit 4.1 below.

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[35] See Baker et al. (2008) for a more technical discussion of this issue, that discusses the underlying social welfare function needed to justify the application of a common VSL across population subgroups.
[36] Ideally, studies would estimate the effects of wealth rather than income alone, but these effects are more difficult to measure.
[37] See Hammitt, Liu, and Liu (2000) for a discussion of the issues that arise when cross-sectional income elasticity estimates are used for longitudinal adjustments.
[38] EPA is currently considering revisions to its VSL guidance.
[39] The details of this approach, particularly the time period over which the adjustment is applied, varies across EPA analyses. See EPA (1999), EPA (2005a), EPA (2005b), and EPA (2006a) for examples.

Exhibit 4.1 APPROACHES FOR VSL INCOME ADJUSTMENTS			
Agency	**Income Elasticity**	**Real Income Measure**	**Inflation Measure**
U.S. Environmental Protection Agency	0.40 (range = 0.08 – 1.00)[a]	Gross Domestic Product per Capita[b]	Consumer Price Index[c]
U.S. Department of Transportation	0.55[d]	Wages and Salary Component of the Employment Cost Index[e]	Consumer Price Index[c]

Sources: EPA (2005b) and EPA (2006a); DOT 2008.
Notes:
a. Based on EPA's l999 literature review; often represented by a triangular distribution.
b. Sources vary, but generally include U.S. Census population data and GDP estimates from the U.S. Bureau of Economic Analysis.
c. Available at: http://www.bls.gov/cpi/home.htm.
d. Based on Viscusi and Aldy (2003).
e. Available at: http://www.bls.gov/ncs/ect/.

The Viscusi and Aldy (2003) meta-analysis cited by DOT provides elasticity estimates using a number of different approaches. First, the authors use their data to re-estimate selected models developed in meta-analyses conducted by Liu, Hammitt and Liu (1997), Miller (2000), Mzorek and Taylor (2002), and Bowland and Beghin (2001). In the four original meta-analyses, these models resulted in mean income elasticity estimates ranging from 0.46 to 1.66. When the models are applied instead to the studies considered by Viscusi and Aldy, the mean elasticity estimates range from 0.51 to 0.61; i.e., the use of a consistent set of studies substantially narrows the range of mean estimates despite the application of different modeling approaches.

Viscusi and Aldy (2003) then evaluate a large number of other model specifications. They present the results for six additional models, using two different regression techniques (ordinary least squares or robust estimation with Huber weights) with the three, four, or eighteen control variables.[40] Perhaps most importantly, only the models with 18 variables control for whether a study used Society of Actuaries' data, which includes risks that are not job-related. The mean income elasticity estimates from these models range from 0.46 to 0.60, with five of the six estimates between 0.46 and 0.51. Thus the researchers' models lead to mean estimates than are somewhat below the estimates that result from the models used in the four earlier studies, and between the best estimates applied by EPA and DOT. The reported elasticity estimates are summarized below.

[40] Robust estimation with Huber weights is a method for dealing with outliers that may otherwise distort the results of the analysis.

Exhibit 4.2 SUMMARY OF INCOME ELASTICITY ESTIMATES FROM VISCUSI AND ALDY 2003	
Regression Model[a]	**Income Elasticity (95 percent confidence interval)**
Liu, Hammitt, and Liu (1997), 46 studies[b]	0.51 (0.21–0.80)
Miller (2000), 49 studies[b]	0.53 (0.20–0.86)
Mrozek and Taylor (2002), 45 studies[b]	0.52 (-0.18–1.22)
Bowland and Beghim (2001), 41 studies[b]	0.61 (0.11–1.10)
Model 1: Ordinary least squares, 3 controls, 46 studies	0.51 (0.21–0.80)
Model 2: Ordinary least squares, 4 controls, 46 studies	0.49 (0.23–0.75)
Model 3: Ordinary least squares, 18 controls, 46 studies	0.60 (0.27–0.94)
Model 4: Robust with Huber weights, 3 controls, 45 studies	0.48 (0.23–0.73)
Model 5: Robust with Huber weights, 4 controls, 45 studies	0.46 (0.24–0.69)
Model 6: Robust with Huber weights, 18 controls, 44 studies	0.47 (0.15–0.78)

Source: Viscusi and Aldy 2003, Tables 6, 7, and 8, pp. 38-42, and Aldy 2008.
Notes:
a. Includes U.S. and non-U.S. wage-risk studies identified by Viscusi and Aldy (2003).
b. Selected model from original meta-analysis re-estimated using studies included in Viscusi and Aldy (2003); some studies are dropped from particular models due to issues related to the data available and model specification.

The ranges provided above are somewhat similar to the ranges found by EPA in its 1999 review of VSL income elasticity estimates, with a few higher and lower values. EPA's review relied largely on the findings of available contingent valuation studies, and (as noted earlier) resulted in a best income elasticity estimate of 0.40 and endpoints at 0.08 and 1.00.[41]

As discussed in Chapter 2, income adjustments have been supported by EPA's expert advisory panels as well as by the Office of Management and Budget (OMB), but are infrequently applied by other agencies. To the extent that CBP or other agencies are using VSL estimates based on previous income levels, such adjustments appear appropriate for use in regulatory analysis. An example of these adjustments, based on the recommendations provided in Chapter 5, is included in the Appendix B to this report.

[41] These studies reviewed by EPA vary in how income is measured, but generally focus on cross-sectional comparisons between different income groups at a particular point in time. Another study, by Costa and Kahn (2004) finds much larger changes derived from U.S. wage-risk estimates calculated for every 10 years between 1940 and 1980. Their preferred elasticity estimates are 1.5 to 1.7, based on the relationship between the VSL estimates from their wage-risk models and changes in the per capita Gross National Product.

4.1.2 Adjustments for Age

The effect of age on the VSL has been an important research topic for many years, particularly in the environmental economics literature. This focus reflects, at least in part, controversy over the appropriate estimates to be used in analyses of air pollution rules. Such rules often disproportionately affect elderly individuals, with about 80 percent of the mortality risk reductions accruing to individuals over the age of 65 (see, for example, EPA 1999). Because these risk reductions primarily affect individuals whose life expectancies are shorter than those of the younger (working-age) individuals addressed in the majority of the VSL studies, there has been substantial debate over whether lower VSL estimates should be used to reflect the smaller number of life years remaining.

These differences may be of lesser concern for homeland security rules because these rules are less likely to disproportionately focus on risks primarily faced by older (or very young) individuals. This section briefly summarizes the relationship of VSL to age or life expectancy, however, because of the importance of the topic in the general debate over the values to be used in Federal regulatory analysis.

As discussed in Hammitt (2007), several factors affect the relationship between age (or life expectancy) and the VSL or VSLY, and there is little theoretical basis for assuming that the VSL increases, decreases, or remains the same at different ages. Some argue that the relationship between VSL and age should follow the pattern of consumption over the lifecycle, which is typically an inverse-U distribution. Aldy and Viscusi (2007) examine the results from revealed preference (primarily wage-risk) studies, and conclude that the VSL follows this pattern, increasing with age in early adulthood, peaking in middle age, and then declining. However, the rate of increase and decrease and the age at which VSL peaks varies across studies. In addition, because these studies focus on working-age individuals, they do not fully address the relationships between age and VSL among those who are older or younger.

The stated preference evidence is less consistent. Krupnick (2007) explores the results from these studies, including contingent valuation surveys and conjoint analyses or choice experiments. He notes a number of issues related to study design and statistical analysis that may affect the findings, and concludes that the results are diverse. Some studies do not find statistically significant relationships between age and the VSL, while others find that the VSL decreases among older individuals in varying patterns and amounts.

Age adjustments are not currently implemented in U.S. regulatory analyses, due to concerns about the empirical evidence as well as equity considerations. Robinson (2007b) discusses EPA's experience, describing the historical application of value per statistical life year (VSLY) estimates (as introduced in Chapter 1) as well as other approaches to adjusting the VSL estimates. EPA no longer adjusts its VSL estimates for age (or life expectancy), both because of controversy related to the perceived inequitable treatment of younger and older individuals (generally referred to as the "senior discount" debate) in policy decisions, and because the results of related research are inconsistent. Most recently, an EPA advisory panel (Cropper et al. 2007) concluded that the empirical evidence is not sufficiently robust to support application of a VSL that varies with age, and that the application of a constant VSLY is not justified.[42]

Valuing children's risks presents a number of difficult problems that have not yet been fully addressed (see, for example, Dockins et al. 2002, EPA 2003).[43] Because children generally lack the independent financial means as well as the cognitive ability needed to address questions about their WTP for risk reductions, it is more feasible to measure parental WTP for reducing risks to children. While the number of such studies is increasing, their implications for regulatory analyses have not yet been thoroughly reviewed. Krupnick (2008) finds that empirical research indicates that parental WTP for reduced morbidity or mortality risks to their children may be roughly twice their WTP to reduce their own risks.[44]

Given the complexities of the issues and the status of related research, Federal agencies generally apply the same VSL estimates for both children and adults. This approach is consistent with the OMB guidance for regulatory analysis, which indicates that "[f]or rules where health gains are expected among both children and adults and you decide to perform a benefit-cost analysis, the monetary values for children should be at least as large as the values for adults (for the same probabilities and outcomes) unless there is specific and compelling evidence to suggest otherwise" (OMB 2003, p. 31).

The mortality risks associated with terrorist acts may not be distributed evenly throughout the population, because the most likely targets include areas with high concentrations of workers. However, some younger and older individuals are also likely to be affected. In other words, the individuals affected may disproportionately include working-age individuals rather than primarily those who are older (or younger). Thus the debate over the relationship between the VSL and age may have limited implications for analyses of homeland security regulations. A key question is whether the VSL estimated from existing studies (which are largely studies of working-age individuals) will be biased when applied to a population that also includes some younger and older individuals. The available research suggests that the VSL may be larger for children and somewhat smaller for older individuals.

[42] Another expert panel recently examined this issue as it relates to premature mortality from ozone air pollution, and recommended the use of a VSL that does not vary by age, while indicating the need for further research. It notes that "the empirical evidence is insufficient to support a specific quantitative adjustment of WTP estimates to account for differences in remaining life expectancy, but it does not reject the general concept that such adjustments may be appropriate." (NAS 2008, p. 7).
[43] In addition, Bloomquist (2004) summarizes recent averting behavior studies that consider mortality risks to children. For the proceedings from 2003 and 2006 EPA workshops featuring on-going valuation research addressing risks to children see:
http://yosemite.epa.gov/EE/epa/eerm.nsf/vwRepNumLookup/EE-0475?OpenDocument and
http://yosemite.epa.gov/ee/epa/eerm.nsf/vwSER/EA5B0CB9C6B74168852571E2004A986C?OpenDocument.
[44] The studies cited in Krupnick (2008) include published articles by Liu et al. (2000) and Dickie and Messman (2004), as well as working papers by Agee and Crocker (2001), Dickie and Ulery (2001), Dickie and Gerking (2003), Jenkins et al. (2003), and Mount et al. (2003).

4.1.3 Adjustments for Health Status[45]

In the absence of the hazards addressed by a particular rulemaking, affected individuals may not be in perfect health. Because health-related quality of life declines with age (e.g., Hanmer et al. 2006), regulations that primarily affect older individuals will largely benefit those who tend to be in worse health than the average member of the population. In addition, some regulations disproportionately benefit individuals who are in poor health regardless of age. For example, pathogens found in drinking water and food often have more severe effects on individuals whose health is impaired, such as those with suppressed immune systems.

Because many of the available VSL estimates rely on data from workers, they are likely to reflect values for individuals in better health than older individuals who have left the workforce or individuals of any age who are not working because of health impairments. Dockins et al. (2006) review the evidence on the effects of health status on the VSL, and note that the theoretical findings are ambiguous. In simple terms, this ambiguity results from the trade-off between spending to increase the likelihood of survival and conserving wealth for expenditure on other goods or services. The effects are potentially counterbalancing: an individual may be willing to pay more for risk reductions if he or she is in good health, but good health may also lead to greater opportunities for other expenditures.[46] The limited empirical research suggests that VSL may be somewhat higher among those whose health is otherwise impaired, but this evidence is weak (e.g., Alberini et al. 2004, DeShazo and Cameron 2005). The effects of health status on the VSL are likely to be correlated with the effects of several other population characteristics, particularly age.

To the extent that terrorism risks are associated with the release of contaminants or other acts that lead to potentially fatal illnesses, individuals in poor health may be more susceptible to the resulting mortality risks. For terrorist acts that involve injuries from explosions or similar causes, health status may have a smaller effect on the likelihood of fatality. Regardless of the health status of those affected, the available research is not sufficient to support adjustment of VSL estimates to reflect these impairments. Similar to the case of age, any adjustments may also raise concerns about the equitable treatment of individuals with different health conditions in Federal policy decisions.

4.1.4 Adjustments for Background Risks

Individuals and populations experience different levels of underlying risks in the absence of the risk being regulated, regardless of their likely health status. For example, an individual

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[45] This factor is often referred to as "baseline" health status in the literature. However, in regulatory analysis, the "baseline" refers to conditions in the absence of the rule (i.e., pre-regulatory conditions, without the risk reduction). In contrast, the health economics literature often uses "baseline" health status to refer to underlying health status in the absence of the risk of concern (analogous to post-regulatory conditions; i.e., after achieving the risk reductions attributable to the rule).

[46] See Hammitt (2000) and Hammitt (2002a) for more detailed discussion of the theoretical issues and related empirical research. Viscusi and Evans (1990) and Sloan et al. (1998) explore the effects of health status on the utility of income; their findings suggest that the marginal utility of income is smaller when health is impaired.

living in a war zone may value mortality risk reductions quite differently than an individual living in a peaceful area. An individual who smokes excessively may value risk reductions differently than an identical individual who does not engage in this sort of behavior, even if their current health status is the same. In other words, individual WTP for a given risk change (e.g., a 1/10,000 decrease in the risk of death) may depend in part on whether he or she is otherwise facing a high or low level of mortality risk.

In theory, individuals facing a high risk of death may be willing to pay an increased amount for current risk reductions because they have fewer competing needs for wealth; i.e., they are "dead anyway" (Pratt and Zeckhauser 1996). However, this effect may be relatively small for most people (Hammitt 2000). In addition, an individual's WTP for a particular risk reduction may be low if the reduction has little overall effect on total mortality risk, particularly if background risks are high (i.e., the "why bother" effect, Eeckhoudt and Hammitt 2001). Empirical estimates of these effects are very limited and the results are mixed (e.g., Evans and Smith 2006).

When valuing mortality risks associated with homeland security regulations, a key issue is whether the available VSL studies reflect the underlying risks faced by the U.S. population affected by the rule. Presumably, recent studies based on a representative sample of the U.S. population are more likely to accurately reflect these risks. The extent to which studies that address different populations or time periods may overstate or understate the VSL due to changes in these background risks is unknown, but the theoretic literature and the limited empirical evidence suggests that the difference will be small in most cases.

4.1.5 Adjustments for Self-Selection

As discussed earlier, many of the available VSL estimates are derived from studies of the wage premia workers accept for riskier jobs.[47] Presumably, the job that each worker selects indicates his or her preferences among the available opportunities, reflecting his or her attitude towards risk as well as other job attributes. In this context, the question arises whether using these studies to calculate a population-wide average VSL will be biased due to the relationship between attitudes towards risk and job choice, or whether any potential bias is adequately addressed by researchers' decisions regarding how to use the data and specify the econometric models. Some have expressed concern that those in higher risk occupations are less risk averse and therefore demand a lower wage premium than would the average individual.[48] As a result, the VSL estimates from the wage-risk studies could understate the average value of risk reductions.

However, the effect of self-selection on the VSL estimated from wage-risk studies is uncertain for both theoretical and practical reasons. As Eeckhoudt and Hammitt (2004) note,

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[47] Exhibit 2.1 reports the average annual risks addressed in selected VSL studies; see Viscusi and Aldy (2003) for a discussion of the relationship between risk and job choice.
[48] Risk aversion can be defined as dislike of risk, in which case it seems self-evident that risk averse individuals would be willing to pay more for risk reductions. In more technical terms, it can be defined as disliking uncertainty or preferring certain over uncertain outcomes. As discussed in Eeckhoudt and Hammitt (2004), this latter type of risk aversion is not logically related to the VSL.

theory suggests that the relationship is ambiguous depending on a number of factors, such as the desire to preserve wealth for bequest purposes. In addition, workers in riskier jobs may be above average in their skill at reducing related risks, which could counterbalance the effects of below average risk aversion to at least some extent (Stavins et al. 2000). In addition, Shogren and Stamland (2002) note that wages are set by the marginal worker but risks are averaged across all workers, which could lead wage-risk studies to overstate the value of mortality risk reductions. In combination, these concerns mean that the effects of self-selection are uncertain, and it is not possible to determine an appropriate quantitative adjustment.

4.2 Differences in Risk Characteristics

Federal agencies rely largely on VSL estimates from studies of job-related accidental deaths, which differ in some respects from the types of risks addressed by many regulations. Available reviews of these risk differences often address environmental health effects and tend to focus on adjustments for (1) risks that result from disease rather than accidents (in particular, the effects of latency and morbidity); and (2) risks that affect others rather than solely one's self (i.e., altruism).[49] While these reviews also discuss the effects of risk perception (e.g., voluntariness, controllability, dread), this issue is addressed in a separate subsection due to its importance in the homeland security context.

4.2.1 Adjustments for Latency and Morbidity

The available VSL estimates rely largely on studies of accidental deaths, which differ in significant respects from deaths due to illness.[50] These differences have been explored in detail in the context of environmental health risks (see, for example, EPA 2000b and IEc 2001). This section briefly reviews two major concerns: latency (or cessation lag) and morbidity prior to death.

Latency and Cessation Lag: For some illnesses (especially cancers), there may be a time lag between the occurrence of the source or cause of the risk (e.g., exposure to a contaminant) and the onset of symptoms. Conversely, there may be a delay between when exposure is reduced and when the full reduction in incidence occurs. These types of latency or cessation lags are not relevant for most fatal injuries, in which case the effect is more immediate. Thus whether adjustments for latency are relevant to the analysis of homeland security regulations will depend on the types of illnesses or injuries averted. For example, a rule that focuses on reducing

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[49] As discussed below, the appropriate treatment of altruism relates to the overall framework for benefit-cost analysis, not solely the approach for valuing mortality risks. It is included in this section, however, because it is listed as a risk characteristic in previous VSL reviews.

[50] While the data sources vary across studies, the most recent wage-risk studies (see Section 3.2) tend to rely on data from the Bureau of Labor Statistic's annual Census of Fatal Occupational Injuries (http://www.bls.gov/iif/oshfat1.htm). From 2001 through 2005, the average annual number of fatalities reported totaled 5,704, with 43 percent from transportation accidents, 15 percent from assaults or violent acts, and the remainder from being struck by objects or equipment, falling, exposure to harmful substances or environments (e.g., electrical currents), or fires and explosions. Most fatalities occurred in private industry, with construction accounting for about 21 percent of the total. The rate of fatalities was about 4 per 100,000 workers in 2005 (BLS 2007).

exposures to cancer-causing substances or radiation may involve significant latency, while latency may not be a concern for a rule focused on reducing explosion-related injuries.

When the results of exposure are not immediately manifest, the term "latency" is generally used to refer to the time lag between a change in exposure and a change in disease incidence. However, in regulatory analyses, agencies are often concerned instead with "cessation lag," which refers to the delay between decreased exposure and achievement of the full reduction in incidence. Much of the research on the duration of these lags addresses cigarette smoking, and suggests that the length of the cessation lag may differ significantly from the latency period (Cropper et al. 2001, EPA 2005a, Sloan et al. 2004).

Until recently, there was little research that directly addressed the effects of such lags on VSL estimates. Thus, for many years, EPA and others have used simple discounting to account for this effect.[51] For example, if a pollution reduction occurs in the current year but a portion of the risk reduction occurs five years later, then EPA would discount the VSL to reflect the five-year delay, using the same rate as applied elsewhere in the analysis.[52] Recent studies appear to support the use of discounted values for delayed impacts (e.g., Hammitt and Liu 2004, Alberini et al. 2006), although the estimates of the amount (or rate) of the discount over time vary.[53]

Homeland security rules differ from environmental rules in two related respects. First, they focus on preventing future risks (from terrorist acts) while environmental rules focus more on reducing current risks (from existing pollution levels). Thus latency (between future exposures and incidence), rather than cessation lag (between reduced exposures and incidence) will be of interest in most cases. Second, deaths from terrorist acts are most likely to result immediately from trauma, while deaths from pollution may more often result from future illness. Thus in the homeland security context, delayed effects often will be less significant.

As noted in Section 1.1, many homeland security rules are designed to address a range of potential terrorist acts, only a small fraction of which may involve hazards with significant latency periods. Adjustments that address the varying latency periods associated with these different hazards would be difficult to develop and may not noticeably affect the resulting values. Adjustment may be desirable, however, for any rules targeted largely on terrorism scenarios that involve radiological or other hazardous contaminants with carcinogenic or other latent effects.

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[51] Discounting VSL estimates for latency or cessation lag is one of several uses of discounting in regulatory analysis. For example, costs and benefits incurred in future years are discounted to reflect their present values, and may vary over time due to phased implementation of regulatory requirements and other factors. In addition, the events prevented by a regulation may occur in different time periods than when the implementation costs are incurred; e.g., regulations that become effective in the current year are likely to avert hazards both now and in the future.

[52] OMB Circular A-4 generally requires that agencies report the results of regulatory analyses using two alternate discount rates (three and seven percent) and also report the undiscounted values over time (OMB 2003).

[53] See Hammitt and Liu (2004) for a detailed discussion of the factors likely to influence the valuation of latent risks. As they note, individual WTP for a mortality risk reduction in the current period may differ from WTP in a future period, because the utility associated with survival is likely to be altered as an individual ages and the world changes (e.g., in terms of opportunities for income and for spending).

Morbidity Prior to Death: When conducting regulatory analyses, Federal agencies generally distinguish between fatal and nonfatal risks when estimating benefit values. Risks categorized as fatal may involve immediate death, as is often the case with severe injuries.[54] Other fatal risks may involve a protracted period of disability or illness before the premature death occurs. This distinction is relevant to the application of VSL estimates from the available research literature because much of this literature focuses on accidental deaths that lack a significant morbidity period.[55] In these cases, agencies may adjust their VSL estimates to reflect the value of averting any morbidity that precedes death for fatal cases. This morbidity may result in increased medical costs, decreased productivity, and the general discomfort, anxiety and depression, and lack of mobility that results from diminished health.

As discussed in more detail elsewhere (e.g., Robinson 2004, Robinson 2007a), agencies value those risks identified as nonfatal using estimates of WTP, quality-adjusted life years (QALYs), and/or averted costs. Each of these approaches has limitations when used to estimate the value of morbidity risk reductions as an increment to VSL. While WTP is the preferred method for valuation, such estimates are not available for many types of morbidity. In addition, some question whether the available estimates effectively distinguish between the value of morbidity and mortality; if not, adding a WTP estimate for a nonfatal illness to a VSL estimate can result in double-counting. QALYs are widely used in cost-effectiveness analysis as well as monetized for use in regulatory benefit-cost analyses. However, a recent expert panel (chartered by OMB and a consortium of Federal agencies) recommended against using this approach in benefit-cost analysis (IOM 2006). Averted costs, including the medical costs of illness and the value of lost household and workplace productivity, are also used for valuation, but are an imperfect measure that is likely to understate WTP for risk reductions.[56]

To address morbidity prior to death, an EPA expert panel (Cropper et al. 2001) suggested adding the medical costs of treatment to VSL estimates as a lower bound estimate for cancers, and noted the need for more WTP research. Such costs are small in comparison to the VSL; for example, EPA estimates that the medical costs of treating a fatal case of bladder cancer are roughly $100,000 (2003 dollars, EPA 2005a). This approach is consistent with the OMB (2003) guidance, which (in its discussion of morbidity valuation) indicates that it is appropriate to add the value of financial externalities not borne by the individual to estimates of individual WTP.

[54] A few types of injuries (particularly traumatic brain injuries and severe spinal injuries) may involve an extended period of disability followed by premature death.

[55] This issue is distinct from the question of whether a VSL study adequately controls for nonfatal risks. In the case of the wage-risk studies, the wage premium associated with fatalities may be overstated if the study does not also control for nonfatal risks, because fatal and nonfatal risks are likely to be correlated, as discussed in Viscusi and Aldy (2003) and Viscusi (2004). In stated preference studies, whether respondents consider morbidity will depend on how the illness is described and whether they interpret the scenario as intended by the researchers.

[56] Some agencies (e.g., FDA, NHTSA) add estimates of monetized QALY losses to estimates of averted costs to capture both the pain and suffering associated with the illness and the economic costs. However, as noted above, a recent expert panel (IOM 2006) recommended against the use of monetized QALYs in these analyses.

On-going work by Cameron and DeShazo on the value of statistical illness profiles (summarized in Section 3.2) is expected to provide additional information on WTP to avert risks that include both morbidity and premature mortality (Cameron and DeShazo 2005, DeShazo and Cameron 2004, DeShazo and Cameron 2005). Other studies are exploring whether WTP varies depending on whether a potentially fatal illness is defined as a cancer or other chronic disease (e.g., Hammitt and Liu 2004).

In the case of homeland security rules, an individual regulation is likely to reduce the probabilities of a range of different types of terrorist events, which in turn are likely to reduce mortality risks associated with a wide range of injuries and illnesses. Given that only some of the affected mortality risks are likely to include a morbidity period, adjusting for this effect may be difficult and may have only a small impact on the results. The exception would be rules targeted narrowly on preventing those types of attacks likely to lead to illnesses that include significant morbidity prior to death.

4.2.2 Adjustments for Altruism

Altruism refers to an individual's concern about the welfare of others, and is not simply a risk characateristic. Whether, and how, to address altruism in benefit-cost analysis is a difficult question that is not particular to the application of VSL estimates nor to the homeland security context. However, because it is often included in discussions of adjustments of VSL for risk characteristics (e.g., EPA 2000a, EPA 2000b, IEc 2001), related issues are briefly summarized below.

As noted in Chapter 1, benefit-cost analysis generally, and the valuation of risk reductions in particular, are grounded in neoclassical economic welfare theory. This framework is based on the notion of consumer sovereignty and assumes that an individual is the best judge of his or her own welfare. In simple terms, economic theory distinguishes between three types of altruism. First, if others bear the costs of a program and I respect their preferences, then what matters is their WTP for the resulting benefits. Second, if instead I bear all the costs of a program that benefits others, then it is my WTP that is important. Third, if I care about the benefits of the program to others but not about the costs they will bear (referred to as "paternalistic" altruism), then the inclusion of my altruistic values may be appropriate. Separating out these types of altruism and determining their dollar value is very challenging, and requires careful consideration to avoid double-counting.

For example, Viscusi, Magat, and Forrest (1988) explored altruistic values for reductions in the risks of insecticide poisonings. While they found that altruistic values may be six times the corresponding private valuations, they note that extrapolating this finding to other contexts is not appropriate for a variety of reasons. One problem is that it is not clear how respondents interpreted the distribution of the costs of each scenario, which makes it difficult to distinguish paternalistic from non-paternalistic altruism.

Given this theoretical framework and the difficulties inherent in attempting to separate different types of altruism, many studies rely on estimates of individual's WTP for reducing their own mortality risks rather than for reducing risks to others. In particular, wage-risk studies reflect an individual's willingness to trade off income for his or her own risk reductions. While individuals may consider the needs of their own household in choosing among different jobs, the resulting values are not likely to reflect their WTP for risk reductions that are spread more widely throughout the population. In contrast, stated preference studies vary in the extent to which they include altruistic motives. Some ask respondents to indicate their private WTP for reductions in their own risks, while others elicit WTP for public programs.[57] The types of altruism captured in the latter studies will depend on the extent to which the respondents believe that they would bear the costs of the program as well as their assumptions about who would benefit. Given these concerns and the lack of empirically-derived adjustment factors, Federal agencies do not adjust VSL estimates to reflect altruistic motives.

4.3 Differences in Risk Perception and Tolerance

Perhaps the most significant difference between the types of risks addressed in the VSL literature and the risks associated with homeland security rules relates to how individuals perceive, or feel about, risks from different causes. As discussed earlier, most VSL research focuses on relatively common hazards (particularly workplace or motor vehicle accidents) that may be perceived as more controllable, voluntary, and familiar, as well as less feared, than the types of rare but potentially catastrophic events associated with terrorist acts.[58] Available evidence suggests that the value of a risk reduction depends in part on these types of qualitative attributes; e.g., a risk of 1/10,000 is likely to be valued differently if it is associated with a terrorist attack rather than with a job-related accident. The literature addressing risk perception is extensive and suggests that these perceptions may significantly influence preferences for government intervention. However, relatively few studies attempt to quantify the effects of these perceptions on valuation.

While the impacts of these perceptions on VSL estimates are often discussed along with the other risk characteristics included in the prior section, they are described separately below due to their importance in the homeland security context. Federal agencies generally do not adjust their VSL estimates for differences in how risks are perceived; however, these differences may be more substantial for terrorism than for environmental and other health and safety hazards.[59]

Given the importance of this issue, this section goes beyond previous reviews. It provides a more in-depth discussion of related research based in part on a presentation prepared to support this report (Hammitt 2008b). It first introduces the general topic of risk perception, then reviews the literature potentially relevant to the valuation of homeland security risks in more detail.

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[57] While Krupnick (2007) identifies a number of newer VSL studies that address public risks, he focuses on the implications of these studies for the relationship of VSL and age rather than for altruistic values.
[58] As noted earlier, job-related fatalities often result from transportation accidents.
[59] As discussed in Section 2.4, for regulations that address the performance of medical technologies (such as X-rays), the Food and Drug Administration at times adjusts its VSL estimates by a small amount ($5,000) to reflect episodes of fear and anxiety related to concerns about one's own health.

4.3.1 Background

The consideration of risk perception is grounded largely in the work of Paul Slovic, Baruch Fischhoff, Sarah Lichtenstein, and their colleagues. These perceptions are psychological in nature: related research recognizes that individuals may rank risks of the same magnitude and outcome differently if they are associated with different causes. In summarizing earlier work (i.e., Slovic, Fischhoff, and Lichtenstein 1980), Slovic (1987) notes that individuals are more likely to want to see a risk reduced through regulation if it is more dreaded (i.e., perceived as more uncontrollable, catastrophic, likely to be fatal, inequitable, risky to future generations, difficult to reduce, risk increasing (rather than decreasing), and/or involuntary). Individuals also have a greater desire for addressing risks that are unknown or unfamiliar (i.e., that are unobservable, unknown to those exposed, new, and/or unknown to science, or have delayed effects).[60]

While these risk characteristics influence the public's willingness to support different programs, including them in valuation may raise concerns about the accuracy, or rationality, of these perceptions. For example, Sunstein (1997) notes that some types of "bad deaths" deserve special attention because they have high externalities, unusual pain and suffering, or result in distributional inequities, but others do not because they reflect perceptual errors or confusion. He concludes that "[i]t follows that valuation of life should not be based on a uniform number per life or per life year saved, but should instead incorporate different social judgments about different kinds of death, to the extent that these judgments can survive critical scrutiny" (p. 276).

In another article, Sunstein (2003) argues that terrorism in particular can lead to excessive reactions, because individuals neglect to consider the low probability of catastrophe when powerful emotions are involved. He notes that government action may still be warranted in such cases, due at least in part to the costs of fear itself. The consideration of fear is also addressed directly by Adler (2004), who argues that fear should be explicitly valued and included in benefit-cost analysis so as to provide a more complete accounting of social welfare impacts.

A critical issue raised by these discussions is where to draw the line between risk perceptions that should, and should not, be included in economic valuation or in government decisionmaking more generally.[61] It may be difficult to agree on which perceptions are irrational "enough" to be excluded from consideration. In some cases, a risk communication or public education program focused on correcting misperceptions could be more cost-effective than additional regulation of the risks of concern. Risk characteristics therefore have a number of implications for how the agencies responsible for dealing with terrorist threats communicate with the public and understand its priorities (see, for example, Jenkins 2006) as well as for valuation.

These concerns suggest two lines of research related to better understanding how risk perception affects the demand for homeland security programs. The first is focused on sorting

[60] For a collection of key articles on risk perception, see Slovic (2000).

[61] Johansson-Stenman (2008) discusses the theoretical relationship between risk perception and WTP, addressing terrorism and other policies and including the effects of fear. He concludes that, when individuals overestimate risk, theory suggests that the effect on WTP is ambiguous.

out the extent to which these perceptions are based on inaccurate information or other problems that may be best solved by better communications. This type of research is on-going, as illustrated by the articles cited above.

The second involves gaining a better understanding of how these issues specifically affect risk valuation. For example, this research would address the premia that individuals would be willing to pay to reduce risks of a given magnitude (e.g., a 1/10,000 change in the annual risk of death) if they result from terrorism or other causes that are particularly feared, rather than from the more commonplace causes usually assessed in the VSL literature. While some research has been completed in this area, it tends to focus on risks that differ in significant respects from those associated with terrorism.[62]

As noted earlier, the effects of risk perception may be one of the most important differences between the scenarios studied in the available VSL research and the scenarios addressed by homeland security rules. Thus to support this report, Dr. James K. Hammitt prepared a workshop presentation that summarized the available research in more detail (Hammitt 2008b), first considering studies that address valuation of risks from sources or causes that vary in terms of their perceived controllability, voluntariness, and other factors, then considering studies that address aversion to ambiguity (i.e., the extent to which individuals prefer known over unknown risks or are tolerant of uncertainty). The following sections provide more information on the studies summarized in that review and discuss their implications.

4.3.2 Effects of Qualitative Attributes

Hammitt (2008b) reviewed the literature on the valuation of risks that differ in how they are perceived and tolerated. He selected eight stated preference studies that appear most relevant to the risks associated with homeland security rules, and divided them into three categories based on whether the valuation scenario addressed a change in one's own risks, in risks to the general public (i.e., the community of which one is a part), or in funding for risk-reducing programs. These studies are introduced in Exhibit 4.3 (in order of publication) and described below.

[62] Some studies consider the value of terrorism events or anti-terrorism programs using metrics other than the value of mortality risks. For example, Gigerenzer (2006) considered the effect of the 9/11 attacks on highway travel, and Viscusi and Zeckhauser (2003) considered the trade-offs inherent in increased airline passenger screening.

Exhibit 4.3 VALUATION STUDIES ADDRESSING RISK PERCEPTION AND TOLERANCE			
Study	**Method (mode of administration)**	**Population Addressed (usable responses)**	**Scenarios Assessed**
Own Risks			
Magat, Viscusi, and Huber (1996)	Choice experiment[a] (computer survey)	Shopping mall recruits in North Carolina (727 respondents)	Choice of residence based on risk of auto fatalities vs. nonfatal nerve disease or fatal or nonfatal lymphoma
Hammitt and Liu (2004)	Contingent valuation (telephone survey)	Random sample in Taiwan (1,248 respondents)	Cancers or diseases of the lung or liver associated with air or drinking water pollution
Carlsson, Johansson, and Matinsson (2004)	Contingent valuation (mail survey)	Random sample in Sweden (996 respondents)	Travel by airplane or taxi
Chilton et al. (2006)	Choice experiment[a] (individuals in small focus groups)	Quota-based selection in the United Kingdom (145 respondents)	Accidents to automobile drivers/ passengers, pedestrians, and in the home; fires in public places and in the home; drowning, rail accidents, hazardous production plant accidents and murder
Community Risks			
Itaoka et al. (2006)	Choice experiment (hand delivered surveys)	Random sample in Japan (1,513 respondents)	Disaster risks from nuclear power generation and routine risks from fossil fuel power generation
Risk-Reducing Policies			
Jones-Lee and Loomes (1995)	Choice experiment[a] (individuals in small focus groups)	Quota-based selection in the United Kingdom (225 respondents)	Roadway and underground railway accidents
Subramanian and Cropper (2000)	Choice experiment[a] (telephone survey)	Random sample in U.S. (1,013 respondents)	Six pairs of public health and environmental health programs
Chilton et al. (2002)	Choice experiment[a] (individuals in small focus groups)	Quota-based selection in the United Kingdom (254 respondents across two studies)	Rail accidents, domestic fires, and fires in public places relative to road accidents
Source: Hammitt (2008b) and the individual studies cited. Notes: a. Survey elicited rates of trade-off between different risk levels or number of deaths, not WTP.			

Own Risks: The first group of studies identified in Hammitt (2008b) addresses individual WTP to reduce one's own risks. Magat, Viscusi, and Huber (1996) asked individuals to choose among residential locations that differ in the risks of chronic disease – peripheral neuropathy (a nerve disease), or lymphoma (cancer of the lymph system). The first disease is generally nonfatal, where as the second occurs in both fatal and nonfatal forms. The researchers also measured respondents' aversion to characteristics of each disease.

This study does not ask individuals to report their WTP, rather it results in risk-risk trade-off ratios that could be applied to adjust WTP estimates. For the scenarios comparing auto fatalities to fatal lymphoma, the median respondent was indifferent to the cause of death, suggesting that there was no difference in his or her WTP across these types of fatal risks. However, it is unclear whether respondents were in part reacting to the latency associated with lymphoma, which may offset the dread associated with cancer but was not specifically described in the survey.

In the second study, Hammitt and Liu (2004) conducted a contingent valuation survey in Taiwan to explore WTP for risk reductions that differ in type (cancer vs. noncancer) and latency, as well as in cause and affected organ (air or drinking water pollution affecting the lung or the liver respectively). They found that reductions in the fatality risks of diseases described as cancers were valued about one-third more than similar diseases not identified as cancers, and that risks of lung disease from air pollution were valued about twice as much as risks of liver disease from drinking water contaminants.

However, their analysis suggests that the magnitude of the risk reduction may not have been fully understood by the respondents. For small risk reductions, economic theory suggests that there should be an approximately linear (or proportional) relationship between the risk change and the change in WTP (see Section 1.2). The authors found that when the risk reduction changed by a factor of four, the change in WTP was less than proportional, changing by a factor of 1.7.

The third study, by Carlsson, Johansson, and Matinsson (2004), compares fatality risk reductions for travel by airplane or taxi, using a contingent valuation survey conducted in Sweden. Respondents were asked to indicate their WTP for a risk reduction from one in one million to 0.5 in one million, under scenarios where the base price of the trip was either the same or different for each transport mode. The two travel modes were chosen to be relatively similar in controllability, and the survey included questions related to the motivation for the WTP responses.

The researchers found that WTP for the risk reduction was twice as high for airplane travel as for taxi travel. They suggest that this difference reflects the perceived suffering associated with air-related fatalities, which some respondents indicated would be more traumatic than those associated with taxi travel. However, respondents were also willing to pay more when the initial price of the trip (prior to the risk reduction) was higher, indicating that their responses were influenced by (or anchored in) the base price; a result which is inconsistent with theory. In addition, many of the respondents indicated that they perceived the risks of flying as higher than the risks of taxi travel, and this perception may have led them to discount the risk information presented in the survey.

The final study addressing one's own fatality risks was conducted by Chilton, Jones-Lee, Kiraly, Metcalf, and Pang (2006) in the United Kingdom. This was another choice experiment that examined individuals' willingness to trade-off different types of risks without eliciting WTP. Respondents participated in small group discussions to ensure that they understood the tasks, then completed the questionnaires individually.

The researchers were interested in exploring the effects of both dread and baseline risks, and first asked respondents to address risks for which the context, or cause, was not identified. The risk scenarios varied only in the baseline risk level, and respondents were asked to indicate their preferred scenario given different incremental risk increases. In a second set of questions, respondents were asked to consider trade-offs between the risks of murder and of fatalities from other causes, including: accidents to automobile drivers/passengers, pedestrians, and in the home; fires in public places and in the home; drowning, rail accidents, and hazardous production plant accidents.[63] The results were then normalized relative to pedestrian accidents, which were identified as the least dreaded risk.

Chilton et al. found that the dread factor (in comparison to pedestrian accidents) was between 0.8 to 1.9 for all of the scenarios except two: it was 5.8 for fires in public places and 8.7 for rail accidents. However, the responses for the context-free risk trade-offs appeared to reflect the use of heuristics (or simple decision rules) that led to irrational responses. The majority of the respondents seemed to try to equalize the total risks (baseline plus increment) of the two scenarios, equating a very small increase in the larger baseline risk with a relatively large increase in the smaller baseline risk, rather than indicating a preference for smaller incremental risk increases. In all four of the above studies, the types of risks addressed are likely to be dreaded less than the risks associated with terrorist acts.

Community risks: In addition to the studies discussed above, Hammitt (2008b) identifies one study that addressed WTP for risk reductions affecting the community. Itaoka, Saito, Krupnick, Adamowicz, and Taniguchi (2006) assessed WTP to reduce mortality risks associated with power generation in Japan. They used a choice experiment to examine the value of risk reductions associated with disasters from nuclear power generation and routine risks from power generation using fossil fuels. They explored scenarios that varied in the baseline risks, the labeling of the sources of the risks, the probability of disaster, and the expected losses from a disaster.

The reported WTP to reduce fatality risks from a nuclear accident was 60 times larger than WTP to reduce fatality risks from on-going fossil fuel generation; however, this result appears to reflect some insensitivity to the risk information presented in the survey. The authors indicate that when risks were labeled as associated with fossil fuel, the labeling reduced WTP relative to equivalent unlabeled risks, while whether nuclear risks were labeled as such had no affect. While the results were sensitive to baseline risks, the researchers found that respondents focused on the potential losses from nuclear disasters and ignored the information on the likelihood that such disasters might occur. In general, the resulting variation in WTP was not proportional to the change in risk, often differing by a substantial amount; the larger estimates for nuclear accidents may reflect the limited sensitivity to the much smaller risk reduction. As a result, the authors note that the VSL estimates calculated from their findings (which are very small compared to other studies) are "generally unreliable for use in valuing mortality risk reductions" (Itaoka et al. 2006, p. 397, fn. 8).

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[63] Estimates of WTP to avert murders are at the high end of the range used to value mortality risks in regulatory analyses; for example, Cohen et al. (2004) estimate WTP to avert a murder at $9.7 million (2000 dollars).

Risk-Reducing Policies: The final three valuation studies discussed in Hammitt (2008b) address choices between policies that affect mortality risks. The first, by Jones-Lee and Loomes (1995) addressed the fatality risks associated with London's underground railway system and with road safety. This is another risk-risk trade-off study (conducted individually in focus groups) that indicates the ratios across different types of fatality risks but does not directly estimate WTP. The authors were interested in investigating the effects of scale, comparing programs to avert a single rail accident with a large number of fatalities to those that would avert a series of smaller rail accidents with the same total number of fatalities. In addition, they explored the effects of the rail vs. road context on preferences for risks of identical magnitude; i.e., the impact of perceived differences in controllability, voluntariness, individual responsibility, and location (underground vs. above ground).

The researchers found little evidence of a scale premium, suggesting that, in the case of rare catastrophic events, aversion to ambiguity may be counterbalanced by doubts about whether programs can be designed to effectively avert such risks. In contrast, they found a more substantial context premium, indicating that risks associated with rail accidents (which were viewed as less controllable and voluntary) were valued 50 percent higher than risks associated with road accidents.

The next study, by Subramanian and Cropper (2000), also explored the trade-offs between different types of risks rather than directly eliciting WTP. The researchers paired six environmental health and public health interventions and asked respondents to consider the number of lives that would need to be saved by each program for them to be indifferent between the two programs. They also asked the respondents to rate the programs in terms of selected attributes and used statistical analysis to explore the effects of these attributes on the results.

The six interventions included: smoking education vs. industrial air pollution control, colon cancer screening vs. drinking water pollution control, dual airbags in automobiles vs. auto emission controls, pneumonia vaccine vs. industrial air pollution control, radon control in the home vs. smoking ban in the workplace, and radon control in the home vs. pesticide ban on fruit. Each pair was designed to address the same type of fatal disease or injury; e.g., heart and lung disease, colon or lung cancer, or traumatic injury. In general, respondents preferred the environmental health programs when both programs would prevent an identical number of deaths. When the number of lives saved was varied, most (but not all) respondents choose the program that saved more lives. However, their choices did not consistently increase (i.e., were not monotonic), suggesting insensitivity to the magnitude of the risk change. The researchers explored the number of lives that each program would need to save for the median respondent to be indifferent between them, and found that the highest ratio was 2.2 to one.

The characteristics of each program considered included four psychological attributes: blame (voluntariness), ease of avoiding risk (controllability), seriousness of the risk (or health problem), and personal risk (likelihood of affecting one's self or one's family). Four program attributes were also assessed: efficacy (effectiveness), appropriateness of government intervention, fairness of program funding source, and the time lag before the lives were saved. The responses suggested that the interventions were viewed as differing more in their psychological attributes than in their program attributes. However, all of the attributes except blame (which was highly correlated with controllability) were found to have a statistically significant effect on the likelihood that a program would be preferred.

The researchers examined the effects of a 100 percent change in each attribute on the percent change in the number of lives saved (i.e., the marginal rate of technical substitution) that would needed to make the respondents indifferent between the two programs. The corresponding change in the number of lives saved is less than 100 percent for all but two attributes (program efficiency and seriousness of the risk), and ranges from 5 percent (for blame) to 150 percent (for the seriousness of the risk). While these findings suggest that risk characteristics influence program choice, the authors note that there is evidence that respondents did not fully accept the scenarios presented by the survey. For example, most respondents did not believe the paired programs would cost the same, contrary to the information provided.

The final study was conducted by Chilton, Covey, Hopkins, Jones-Lee, Loomes, Pidgeon, and Spencer (2002) and included two surveys, conducted before and after a major rail accident in London. The researchers compared the value of programs that would reduce fatality risks from rail transportation, domestic fires, and fires in public places to the value of programs addressing road safety. The approach was similar to that used in the Jones-Lee and Loomes (1995) and Chilton et al. (2006) studies discussed earlier, each of which presented questionnaires in small focus groups. In this study, the respondents were asked to indicate the extent to which they would trade-off the number of deaths prevented by each program. The researchers also collected information on seven attributes: scale (number of people killed per event), personal control over risks, voluntariness of exposure to risks, media attention, how much experts knew about the risks, uneasiness, and the benefits to themselves and their households. The researchers provided data on the number of deaths each year from each cause and on the age groups affected, and asked respondents to indicate the extent to which these data affected their choices.

The researchers found that these attributes affected the priorities the respondents placed on the programs. However, the attributes had a relatively small effect on respondents' willingness to trade-off the number of deaths prevented by each program; the difference was generally less than 20 percent.

Exhibit 4.4 summarizes the results of these studies, presenting the central tendency estimates reported for the scenarios involving mortality risks that differ in type or cause. The underlying studies face several challenges as noted above, and are inconsistent in the extent to which they report data on the precision of the resulting estimates.

Exhibit 4.4 EFFECTS OF RISK PERCEPTION AND TOLERANCE ON THE VALUE OF MORTALITY RISKS		
Study	**Key Findings**	**Ratio[a]**
Own Risks		
Magat, Viscusi, and Huber (1996)	No difference between auto fatalities and fatal lymphoma	1/1
Hammitt and Liu (2004)	Cancers valued one-third more than noncancers Air pollution risks valued at twice the risks from drinking water	1.3/1 2/1
Carlsson, Johansson, and Matinsson (2004)	Risk reductions valued twice as high for air travel as for taxi travel	2/1
Chilton et al. (2006)	Dread factor ranging from 0.8 to 1.9 (in comparison to pedestrian accidents) for all scenarios except fires in public places (5.8) and rail accidents (8.7)	0.8/1 to 8.7/1
Community Risks		
Itaoka et al. (2006)	Fatalities from nuclear power disasters valued 60 times higher than fatalities from routine fossil fuel generation.	60/1
Risk Reducing Policies		
Jones-Lee and Loomes (1995)	No differences attributable to scale of accident. Rail-related risk reductions valued 50 percent higher than road-related risks.	1/1 1.5/1
Subramanian and Cropper (2000)	A 100 percent change in each attribute (blame, ease of avoidance, seriousness, personal impact, program effectiveness, appropriateness of intervention, fairness of funding, and the time lag) led to a 5 to 150 percent change in the risk trade-off.	1.05/1 to 2.5/1
Chilton et al. (2002)	The value of preventing deaths from rail accidents and fires was at most 20 percent higher than the value of preventing road accidents.	≤1.2/1
Source: Hammitt (2008) and the individual studies cited. Note: a. As discussed in the text, these ratios should be interpreted with caution given the limitations of the underlying studies. For example, some are based on small surveys using convenience samples, and there is evidence in many cases that the respondents did not interpret the survey scenario as intended by the researchers. The studies vary in the extent to which they report quantified measures of the degree of uncertainty in these estimates.		

In sum, most of these studies indicate that the value of preventing fatalities is likely to be influenced by the qualitative attributes of the context or cause, although the extent of the effect varies depending on the study methodology and the types of risks examined. In addition, most of the risks studied to-date may be less feared, and perceived as more voluntary and controllable, than the risks of terrorist acts, which suggests that the premium placed on averting related fatalities may be higher than the values found in these studies.

These studies have a number of other limitations that suggest that more research would be useful. In particular, several rely on very small samples that may not be representative of the population studied. In addition, many include findings that suggest that respondents did not accept or understand some aspects of the scenarios presented, and did not fully take into account the magnitude of the risk change. Hence improvements in survey design and administration are needed to address these concerns.

4.3.3 Effects of Ambiguity Aversion

One issue raised by some of the above studies is how aversion to ambiguous risks (i.e., to probabilities that are not known with precision) affects risk perception and valuation.[64] This concern is of particular importance in the context of homeland security. Because terrorist acts occur infrequently, it is difficult (if not impossible) to predict future occurrences with reasonable certainty based on past experience. Thus the values that individuals place on averting related mortality risks may in part reflect their aversion to the ambiguity of the risk information.

Hammitt (2008b) identifies three additional studies that address this issue. First, Viscusi, Magat, and Huber (1991b) explore the effects of ambiguity aversion on an individual's willingness to trade-off the risks of nerve disease or lymphoma associated with living in two areas. This study is very similar to the risk-risk study by the same authors discussed earlier (Magat, Viscusi, and Huber 1996), and was administered by computer to 646 individuals intercepted in a North Carolina shopping mall. In this case, however, the trade-off was between a location ("Area A") with two (ambiguous) risk estimates, and a second location ("Area B") with a single risk estimate for the disease of concern.

The researchers found that, when making these trade-offs, individuals did not respond as if they simply averaged the two risk estimates for Area A when comparing it to Area B.[65] Instead, respondents appeared to perceive the risk levels as above the average when there was more ambiguity (or difference) between the two Area A estimates. They also reacted to the order in which the estimates were presented, viewing risks as higher if the larger risk estimate was presented second or reported as derived more recently. In addition, if the distribution of the risks was reported as asymmetric, respondents tended to focus on the end of the distribution that had the highest (worst case) risk. Although the median differences in responses were relatively small, the researchers found that risk ambiguity increased the likelihood of extreme responses, where individuals reacted primarily to the high or low estimates presented.

A second study was conducted by Shogren (2005), and reported in an article on integrating economics and biomedical research when developing health and nutrition policy. He notes that one of the major research challenges is developing a better understanding of how human behavior deviates from the assumptions of rationality that underlie the traditional economic model. Shogren presents the results of a contingent valuation survey that assesses the impact of ambiguous probabilities on WTP to decrease the likelihood of food-borne illness. This

[64] In his seminal work on this topic, Ellsberg (1961) notes that ambiguity depends on the amount, type, reliability, and unanimity of information on probabilities and the resulting degree of confidence one has in the data. He indicates that many people prefer payments that they will receive with certainty to those that are uncertain, even when the uncertain outcome has a higher expected value.

[65] Theory suggests that individuals should average the risks if they are attempting to maximize their own utility. However, the authors note that, when individuals are making sequential decisions, theory suggests that they should prefer the more ambiguous risk since it provides the opportunity for learning and adaptation.

survey asked individuals to state their WTP to eliminate the chance of illness at each of two restaurants. For one restaurant, two food safety inspectors agreed about the current risk level. For the second, the inspectors disagreed and two different estimates of risk were presented. The survey also asks which restaurant the respondent would prefer if both offered the same prices.

Shogren found that, while mean WTP estimates were usually higher for the ambiguous risk scenario (generally by a factor of about 1.3 to 2), the medians were often not significantly different from the estimates for the unambiguous risk scenario. In addition, he found that the respondents did not distinguish between different risk levels, reporting WTP estimates that decreased by only about 74 percent as the risk decreased by orders of magnitude (from 1/10 to 1/10,000,000).

In the final study, Riddel and Shaw (2006) develop a model that allows variation in the estimate of the risk itself (i.e., the likelihood of mortality) and of the ambiguity in this risk estimate (i.e., the range of estimates). They then use this model to analyze the results of a contingent valuation survey that explores individual willingness to accept (WTA) compensation for incurring the risks associated with nuclear waste transport. The survey was administered to a sample of Nevada residents using a combination of mail and phone contacts. Respondents were asked to use a risk ladder to indicate the risks they believed were associated with nuclear waste transport, after reviewing estimates developed by Department of Energy experts, and were allowed to report their subjective risk estimates as a single point or as a range. They were then asked whether they would accept varying amounts of compensation to continue living in the same location if waste was routed through the area, or would prefer to move, assuming that relocation costs would be borne by the government.

The researchers found that respondents' perceived risks were thousands of times higher than those from the Department of Energy. Based on these subjective risk estimates, the reported WTA amounts implied a mean VSL of $5.45 million. The results also suggested that WTA rises as ambiguity increases (i.e., as the range of subjective risk estimates becomes wider). For example, if the ambiguity increases by a factor of two (e.g., from a point estimate of probability "p" to a range from zero to twice "p"), VSL increases by 75 percent.[66]

These studies suggest that individual WTP is likely to be higher for ambiguous risks than for risks that are better understood.[67] Because terrorist events happen infrequently, data are not available that can be used to estimate the baseline likelihood of attack nor the change in this likelihood attributable to a particular rule. Estimates instead are based on experts' judgments, and experts are likely to disagree. In addition, experts' opinions may diverge from potentially

[66] Calculated by Dr. Hammitt by dividing twice the coefficient for ambiguity (2 x -0.3) by the coefficient for risk (-0.8) from Riddel and Shaw (2006), Table 2, p. 144. (Personal communication from James Hammitt, April 2008.)
[67] The effect of improved information is illustrated in another study by Gayer, Hamilton and Viscusi (2000), who find that WTP estimates decrease as residents learn more about the risks associated with Superfund sites.

affected individuals' perceptions of the probability of attack. Thus terrorism risks are likely to be perceived as highly ambiguous.[68]

4.4 Summary and Conclusions

Research on the VSL focuses on scenarios that differ in significant respects from the scenarios addressed by homeland security rules, but analysts' ability to quantitatively adjust the estimates to address these differences is limited by the available empirical research. Reviews of potential adjustments often focus on environmental risks, which differ from the risks typically studied as well as from the risks associated with homeland security rules. Thus the adjustments that are relevant or appropriate in the homeland security context will differ in some respects from those recommended for use in environmental or other policy analyses.

More generally, scenario differences can be categorized by whether they relate to the characteristics of the population affected or the risks that are averted. These differences are often correlated and it can be difficult to separate out their interrelationships. Exhibit 4.5 provides a simple summary of the key differences discussed in this chapter; its implications are described below.

[68] One option for adjusting for ambiguity involves addressing the probabilities used rather than the VSL estimates themselves (Hammitt 2008b). For example, rather than using a probability of fatality that averages estimates from different experts (or experts and lay person views), the probability could be weighted towards the higher end of the range to reflect the fact that individuals place higher values on ambiguous risks than on risks that are more certain.

Exhibit 4.5 EFFECTS OF SCENARIO DIFFERENCES		
Characteristic	**Empirical Evidence**	**Implications for Homeland Security Rules**
Population Characteristics		
Income	Many studies; VSL increases as real income increases.	Adjust VSL to reflect real income growth over time.
Age (life expectancy)	Many studies; results inconsistent.	No adjustment.
Underlying Health Status	Limited; uncertain effect.	No adjustment.
Background Risks	Limited; uncertain effect.	No adjustment.
Self-selection	Limited; uncertain effect.	No adjustment.
Risk Characteristics		
Latency and Morbidity	Limited; magnitude of effect uncertain, simple adjustments possible.	Adjust if regulation is targeted on risks with significant latency periods or morbidity prior to death.
Altruism	Limited; uncertain effect.	No adjustment.
Risk Perception (source or cause)	Limited; averting homeland security risks may be valued more highly than averting the risks commonly studied.	Provide illustrative adjustments in sensitivity analysis.

The population characteristics explored in recent reviews of the VSL literature include income, age (or life expectancy), health status, background risks, and selection bias. The effect of income is clear and measurable: higher income individuals generally report larger WTP amounts for a given mortality risk reduction, resulting in higher VSL estimates. As discussed earlier, agencies generally only adjust for real per-capita income growth longitudinally (over time); the adjustments are not applied cross-sectionally (across different population subgroups) due to concerns about the perception of inequitable treatment of richer and poorer segments of the population in policy decisions.

Agencies generally do not adjust for the other population characteristics listed in Exhibit 4.5 due to limitations in the underlying research as well as concerns about how the adjustments might be perceived. In particular, adjustments for age have been controversial. This debate has been driven largely by questions related to the appropriate VSL to be used for air pollution rules (where changes in mortality risks tend to predominately benefit older individuals), and the theoretical and empirical evidence is somewhat mixed. Differences related to age or health status may be of lesser concern for homeland security rules because such rules are not as likely to disproportionately affect the risks faced by older (or younger) individuals or by those in poor health. The effects of background risks and self-selection are ambiguous and not as well-studied.

Scenario differences related to risk characteristics include latency and morbidity, altruism, and risk perception. Latency and morbidity are associated primarily with the differences between the accidental deaths considered in most VSL studies and the illnesses addressed by some regulations. In both cases, simple adjustments are possible. When illness involves a time lag between exposure and incidence (i.e., latency or cessation lag), discounting is often used to reflect the effect of this timing. When mortality is preceded by a period of morbidity, medical costs may be added to the VSL to provide a lower bound estimate of its value. These adjustments may be relatively unimportant in the homeland security context, however, because most rules are likely to predominately avert immediate deaths from trauma rather than from lingering illnesses. Risks that involve significant latency or morbidity may be a relatively small portion of the overall risks averted by anti-terrorism rules.

Most VSL research considers individuals' WTP for reducing their own risks rather than for reducing risks to others. Whether and how to address altruism in benefit-cost analysis in general, as well as in the valuation of mortality risks, is a difficult question, however. It requires clarifying who bears the costs of the program as well as whether they respect the preferences of those who benefit. Separating out different types of altruism and determining their impact on valuation is challenging and requires careful consideration to avoid double-counting. Hence the VSL is generally not adjusted for altruism in Federal regulatory analyses.

Perhaps the most important category of risk characteristics in the homeland security context relates to how they are perceived. The available VSL studies generally focus on relatively common risks (particularly workplace or motor vehicle accidents). Individual WTP to reduce these types of risks may differ from WTP to reduce risks from terrorism or other infrequent but potentially catastrophic events. Terrorism is an intentional act rather than accidental, and is likely to be viewed as less controllable, voluntary, and familiar, as well as more ambiguous, than the risks usually studied.

Available research suggests that individuals are more supportive of public programs that address these types of risks, and that risks with these types of attributes may be assigned a value that is larger than the value of more familiar or less ambiguous risks. However, most of the risks studied to-date may be less feared and better understood than those associated with terrorist threats, and hence the premium placed on averting terrorism-related fatalities may be higher than the values found in these studies. In addition, the available studies of risk premia have a number of limitations that suggest that more research is needed.

5.0 IMPLICATIONS AND RECOMMENDATIONS

The information provided in this report has a number of implications for valuing mortality risk reductions (i.e., for estimating the value per statistical life – VSL) associated with homeland security regulations. These implications were discussed in a workshop with three leading experts as well as U.S. Customs and Border Protection (CBP) and other Department of Homeland Security (DHS) staff, and their suggestions have been incorporated into this report. This chapter first summarizes the process used to collaborate with the experts, then presents the resulting recommendations.

5.1 VSL Expert Workshop

To develop recommendations for valuing mortality risks in its regulatory analyses, CBP followed a three-step process.

- First, CBP commissioned an initial draft of this report, to review current agency practices and the available research literature as well as suggest next steps. The report was developed by Lisa A. Robinson for Jennifer Baxter of Industrial Economics, Incorporated (IEc), then reviewed by IEc and CBP staff and by Dr. James K. Hammitt (Harvard University), and revised as needed.

- Second, CBP funded a workshop, organized by Ms. Robinson under the auspices of IEc and involving three experts: Dr. Hammitt, Dr. Joseph E. Aldy (Resources for the Future), and Dr. Alan Krupnick (Resources for the Future). These experts were selected because each has contributed significantly to the research used to estimate the VSL in Federal regulatory analyses.

- Third, CBP supported revision of this report, to incorporate the recommendations and comments received from the experts and others, supplemented by additional research. The revised report was reviewed by the experts as well as by IEc and DHS staff before it was finalized.

The workshop was held at DHS offices on March 7, 2008. Prior to the workshop, the experts and other participants prepared presentations that reflected the available research, including the information provided in the initial draft of this report and the results of their own investigations. These presentations addressed the context for the effort (Baxter 2008), current Federal agency practices (Robinson 2008), basic VSL concepts (Hammitt 2008a), sources of base VSL estimates (Aldy 2008), risk characteristics (Hammitt 2008b), and population characteristics (Krupnick 2008). Each topic was then discussed among the workshop participants, who included David Houser and Charlotte Oliver (Office of General Counsel, DHS), Elena Ryan and Brett Gelso (CBP), and Jennifer Baxter and Henry Roman (IEc) as well as Ms. Robinson and the three experts. In addition to developing recommended VSL estimates for immediate use in homeland security regulatory analyses, the group discussed research priorities for refining the approach.

The contents of the presentations were then incorporated into the preceding chapters of this report, supplemented by additional research as necessary. The remainder of this chapter summarizes the resulting recommendations.

5.2 Conclusions and Recommendations

The goal of this report and the related workshop was to develop an approach for estimating the VSL in homeland security regulatory analyses that could be implemented immediately without further research. This approach relies on well-established benefit transfer techniques for the VSL (as discussed in the preceding chapters), because the populations and risks studied in the research literature differ in some respects from those associated with homeland security rules. The benefit transfer framework requires reviewing available studies to determine their quality (in terms of the data and methods used) and suitability (in terms of the similarity of the studied populations and risks), as well as evaluating options for adjusting the research estimates to better match the regulatory scenarios. The following sections present this framework, then apply it to recommend an approach for valuing the mortality risks associated with homeland security rules.

5.2.1 Benefit Transfer Considerations

Review of completed homeland security regulatory analyses (see Section 1.1) suggests that it is difficult to characterize the populations and risks affected by these rules in detail. The numbers and types of terrorist attacks averted by a particular rule are almost impossible to predict with a reasonable level of confidence or precision. DHS instead relies largely on breakeven analysis, comparing the costs of each rule to the change in the likelihood of various types of attacks that would be needed for the benefits of the rule to exceed these costs. These analyses often consider a range of different attack scenarios. Available evidence suggests, however, that the population affected is likely to be urban and may disproportionately include working-age adults, given the focus of terrorists on targets in large cities that serve as places of employment. In addition, the mortality risks are more likely to involve immediate death from severe trauma rather than from lingering illness.

Thus in applying the benefit transfer framework, this report assumes that: (1) most homeland security rules are likely to address multiple attack scenarios; (2) averted deaths would most likely result immediately from severe injury; and (3) workers may be disproportionately affected. It also discusses the implications of other scenarios which may be more narrowly focused on particular targets or modes of attack, may include deaths from longer term impacts (e.g., associated with chronic illness from exposure to chemical, biological, or radiological contaminants), and may affect other types of locations and/or age groups.

When valuing mortality risks, Federal agencies generally implement this benefit transfer framework by following a two step process. First, they derive a base VSL estimate from the available studies, then they adjust it for scenario differences. These steps are discussed below.

5.2.2 Base VSL Estimates

As discussed in Chapter 2, Federal agencies currently vary in how they value mortality risk reductions, but their VSL estimates are generally within the $1 million to $10 million range identified in the Office of Management and Budget's (OMB's) 2003 guidance. These estimates are based largely on available meta-analyses, which combine the results from several studies. However, as described in Chapter 3, many of the studies included in these meta-analyses rely on relatively old data and methods that are not fully consistent with currently accepted best practices. While the key meta-analyses were published between 2000 and 2006, the studies they include were published between 1974 and 2002 and generally rely on data collected several years before their publication dates. A recent U.S. Environmental Protection Agency (EPA) expert panel review (EPA 2006b, Cropper et al. 2007), suggested that a number of improvements are needed in these meta-analyses, including refined criteria for selecting studies and enhanced methods for statistical analysis. These recommendations have not yet been incorporated into the approaches used to estimate the VSL by Federal agencies.

Review of the available research suggests that the latest U.S. wage-risk studies rely on data and methods that may be more appropriate for the valuation of homeland security-related mortality risks. These studies assess the relationship between job-related risks and workers' wages, using statistical models to separate out the effect of other factors on these relationships. As discussed in Chapter 3, recent analyses (particularly Viscusi 2004 and Aldy and Viscusi forthcoming) rely on data sources that better account for job-related risks (i.e., the Census of Fatal Occupational Injuries) and also use more recent labor market data from the Current Population Survey. They apply improved methods for modeling the likely relationship between job-related risks and wages, considering risks by occupation and industry as well as controlling for the effects of nonfatal injury risks, workers' compensation, unionization, age, gender, education, and other factors. Thus the quality of these recent studies generally represents an improvement over those included in the earlier meta-analyses.

The population addressed by these recent wage-risk studies also seems relatively similar to the population most likely to be affected by homeland security rules, because the studies focus on working-aged individuals. While homeland security risks also affect younger and older individuals, workers may be disproportionately affected. The extent to which the exclusion of younger and older individuals from the wage-risk studies leads to bias is uncertain, because the impacts are likely to be at least somewhat offsetting. Available evidence (discussed in Section 4.1.2) suggests that the value of averting risks to children may be significantly higher than averting risks to adults, and that the values reported by older individuals may be somewhat lower. The net effect will depend on the proportion of the affected population that falls into each age group.

In addition, the risks addressed by the wage-risk studies primarily relate to death from severe trauma. Workplace fatalities are dominated by transportation accidents (43 percent of fatalities in 2001 through 2005) and assaults or violent acts (15 percent), with the remainder from being struck by objects or equipment, falling, exposure to harmful substances or environments (e.g., electrical currents), or fires and explosions (BLS 2007). Thus while the context for these deaths differs (job-related rather than terrorism), the types of deaths (usually severe trauma rather than illness) are similar.

Of the two recent wage-risk studies reviewed in Chapter 3, Viscusi (2004) appears to provide the most appropriate foundation for developing base VSL estimates for homeland security rules. The Aldy and Viscusi (forthcoming) research uses similar data and methods and results in comparable VSL estimates, but is focused primarily on exploring the effects of age on the VSL. In contrast, Viscusi (2004) is focused specifically on improved VSL estimates.

Thus, based on the quality and applicability considerations discussed above, this report recommends relying on the Viscusi (2004) study for the base VSL estimates to be applied in homeland security regulatory analyses. The best estimate from this study (in 1997 dollars) is $4.7 million, derived from the model that is most complete; i.e., includes data from the full sample and controls for other variables (such as nonfatal risks) that influence the relationship between fatality risks and wages.[69] When inflated to 2007 dollars, this estimate increases to $6.1 million (prior to adjustment for real income growth), with a 95 percent confidence interval of $4.8 million to $7.6 million (see Appendix A).[70] If adjusted for real income growth as well as inflation (as discussed below and in Appendix B), these values increase to a best estimate of $6.3 million with a range of $4.9 million to $7.9 million.[71]

In comparison, as summarized in Exhibit 5.1, recent Department of Transportation guidance (DOT 2008) provides a best estimate of $5.8 million in 2007 dollars, adjusted for both inflation and income growth. The best estimate used by the U.S. Environmental Protection Agency's Office of Air and Radiation is $6.8 million (EPA 2006a), while the best estimate used by other EPA offices is $7.6 million (EPA 2000a), when inflated to 2007 dollars without adjustment for income growth. The recommended homeland security estimates are within the $1 million to $10 million range (no dollar year reported) discussed in the 2003 OMB guidance as well as similar to those used by other agencies, as described in more detail in the previous chapters.

[69] In particular, this model uses data for 1992 through 1997 on fatality risks by occupation and industry, controls for the risk of injury and illness and for worker's compensation as well as other potentially confounding variables, and defines wages in log form.
[70] Confidence intervals for the VSL are not reported in Viscusi (2004). The interval reported above was calculated by Dr. Aldy (based on consultation with Viscusi), as reported in Appendix A. Because Aldy's analysis suggests that the distribution is approximately normal, a normal distribution may be used for probabilistic analysis of uncertainty.
[71] As noted in Appendix A, Aldy's re-estimated results reflect in a slightly larger mean VSL than the original study (rounding to $4.8 million instead of to $4.7 million in 1997 dollars). For consistency with the original study, we continue to use a mean of $4.7 million given the small difference in the estimates.

Exhibit 5.1 COMPARISON OF BASE ESTIMATES[a]			
Agency	**Reported Values (range, dollar year)[b]**	**Inflated to 2007 Dollars (range)[c]**	**Basis**
EPA – Air Office (e.g., EPA 2006)	$5.5 million ($1.0 million-$10 million, 1999 dollars)	$6.9 million ($1.2 million-$12.5 million)	Mzorek and Taylor (2002) and Viscusi and Aldy (2003) meta-analyses.
EPA – Other Offices (2000 guidance)	$4.8 million ($0.6 million-$13.5 million, 1990 dollars)	$7.6 million ($1.0 million-$21.4 million)	Viscusi (1992, 1993) literature review.
DOT (2008 guidance)	$5.8 million (sensitivity analysis: $3.2 million and $8.4 million; probabilistic analysis: standard deviation of $2.6 million, 2007 dollars)[d]		Kochi et al. (2006), Miller (2000), Mrozek and Taylor (2002), and Viscusi and Aldy (2003) meta-analyses; Viscusi (2004) wage-risk study.
FDA (e.g., FDA 2005)	$5 million (varies, no dollar year reported)		No formal guidance, generally cites literature reviews and meta-analyses.
Other agencies	Economically significant rules addressing mortality risks infrequent, approaches generally similar to the above.		
Homeland Security Recommendations	**$6.1 million ($4.8 million – $7.6 million, 2007 dollars)[e]**		**Viscusi (2004) wage-risk study.**

Notes:
a. See Chapter 2 for more information on agency estimates.
b. Estimates reported in agency documents.
c. Inflated by the author using the Consumer Price Index - All Urban Consumers (CPI-U, http://www.bls.gov/CPI/).
d. DOT reports its base estimates with adjustment for real income growth as well as inflation; other agencies report base estimates adjusted only for inflation.
e. Inflation adjusted only, increases to $6.3 million (with a range of $4.9 million to $7.9 million) if also adjusted for real income growth over time.

5.2.3 Adjustments for Scenario Differences

Review of the evidence on the effects of scenario differences (in Chapter 4) indicates that, in most cases, data are lacking to support quantitative adjustments. However, the information in that chapter can be used to discuss the implications of related uncertainties. In addition, Federal agencies generally do not adjust VSL estimates to reflect cross-sectional differences in individual willingness to pay across population subgroups, because the use of estimates that vary across subpopulations has led to the perception of inequitable treatment in policy decisions. Instead, agencies generally apply estimates that reflect population averages.

This section focuses on those areas where quantitative adjustments are possible, including adjustments for changes in real income over time and for certain dissimilarities between deaths from illness rather than injury (latency and cessation lag, morbidity prior to death). Given the importance of differences in how homeland security risks are perceived in comparison to other risks, illustrative analysis of the impacts of these differences also may be desirable. The recommendations for each of these adjustments are discussed in more detail below.

Changes in real income over time: Adjusting the VSL for longitudinal changes in real income requires two types of data: estimates of the relationship between the change in real income and the change in the VSL (i.e., the income elasticity), and estimates of the change in real income over time. Section 4.1.1 introduces sources of these data, and related calculations are discussed in more detail in Appendix B.

A key issue is the match between the data used to develop the base VSL estimates and the data used for the income adjustment. Because the base VSL estimates discussed above are derived from a recent wage-risk study (Viscusi 2004), we focus on estimates of elasticity and real income growth that rely on similar data and methods. Specifically, we rely on income elasticity estimates from the Viscusi and Aldy (2003) analysis of wage-risk data, as presented in Exhibit 4.2. Viscusi and Aldy estimate elasticity using several different models, and find mean estimates ranging from 0.46 to 0.61. In other words, for each 1.0 percent change in real income, the VSL is expected to increase by 0.46 to 0.61 percent. Review of the underlying models suggests that the best elasticity estimates may be those provided by Viscusi and Aldy's Model 6. This model controls for the largest number of variables that may influence the estimates and also includes an adjustment for outliers that may distort the results. It provides elasticity estimates at the low end of the overall range reported across their models, resulting in conservative estimates of the relationship between income and the VSL.

The income elasticity estimates from this preferred model include a mean of 0.47 and a 95 percent confidence interval ranging from 0.15 to 0.78.[72] This mean is slightly above the best estimate (0.40) currently used by EPA and below the estimate (0.55) used by DOT; the confidence interval includes the best estimates applied by each agency. The interval is somewhat narrower than the range used by EPA (0.08 to 1.00), which is based largely on the contingent valuation studies available when it conducted its 1999 literature review.[73]

The second input into the analysis involves estimating the change in real income over time. We rely on data from the Current Population Survey, which is undertaken jointly by the Bureau of Census (in the U.S. Department of Commerce) and the Bureau of Labor Statistics (in the U.S. Department of Labor), as discussed in more detail in Appendix B. This survey is the source of earnings data for the Viscusi (2004) study used to develop the base VSL estimates; it is also the source of the earnings data for several of the studies used to develop the income elasticity estimates (in Viscusi and Aldy 2003).

This source of earnings data differs from those used by other agencies, in part because each agency relies on different sources for its base VSL estimates. As discussed in Section 4.1.1, EPA generally relies on estimates of the change in real per capita Gross Domestic Product (GDP), which is a broad measure of overall productivity. DOT instead relies on the wages and salaries component of the Employment Cost Index, which is weighted by industry and

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[72] The income elasticity estimates are normally distributed (personal communication from Joseph Aldy, May 2008).
[73] DOT uses a single elasticity estimate rather than a range.

occupation. Review of these sources suggests that the extent to which they provide similar estimates of the growth rate varies depending on the time period considered. Generally the Current Population Survey and the Employment Cost Index appear to result in somewhat similar estimates of the rate of change, while per capita GDP appears to be growing at a somewhat faster rate.

As noted earlier, adjusting the recommended base VSL estimates for both inflation and real income growth leads to a best estimate (in 2007 dollars) of $6.3 million, with a range of $4.9 million to $7.9 million.[74] This range can be used for simple sensitivity analysis. If probabilistic analysis is used instead to assess uncertainty, then both the base VSL estimates and the elasticity estimates can be entered as separate normal distributions.[75]

Differences between illness and injury-related risks: As discussed earlier, the wage-risk studies primarily address relatively immediate deaths from injuries, rather than deaths from lingering illnesses. In cases where a homeland security rule focuses on illness-related deaths, simple adjustments are possible. When illness involves a time lag between exposure and incidence (i.e., latency or cessation lag), discounting can be used to reflect this timing. When mortality is preceded by a period of morbidity, medical costs may be added to the VSL to provide a lower bound estimate of its value.[76] These adjustments may be relatively unimportant in the homeland security context, however, because related rules are likely to more often avert immediate deaths from trauma rather than deaths from lingering illnesses.

Differences between job-related and homeland security risk perceptions: Perhaps the most important category of risk characteristics in the homeland security context relates to how they are perceived. The available VSL studies generally focus on relatively common risks (particularly workplace or motor vehicle accidents). Terrorism is an intentional act rather than accidental, low in probability yet potentially catastrophic, and likely to be viewed as less controllable, voluntary, and familiar than the risks usually studied. In addition, the probability of related fatalities are ambiguous as well as small; experts are unlikely to agree on their likelihood.

More research is needed to fully assess the effects of these attributes on the VSL, as discussed in Section 4.3. However, if we eliminate the more problematic studies, it appears that more involuntary, uncontrollable, and dread risks may be assigned a value that is perhaps twice the value of more familiar risks (see Exhibit 4.4). Thus DHS may wish to explore the effects of

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[74] This range was calculated by adjusting the 95 percent confidence interval values for income growth using the mean elasticity estimate of 0.47 in all cases (following the approach illustrated in Appendix B). It does not apply the low (or high) elasticity estimates, because combining low or high end estimates for both the base VSL and income elasticity will lead to an income-adjusted estimate that is unlikely. The probability that both values are in fact near the low or high ends of their respective ranges is likely to be small.

[75] In this case, the real income growth estimate from the CPS also can be entered as a separate distribution if desired.

[76] This adjustment refers to the period of illness preceding death for those cases that result in premature mortality, rather than to the valuation of nonfatal illnesses associated with terrorist acts. As discussed earlier, the Viscusi (2004) VSL estimates are derived from a regression model that controls for nonfatal risks.

doubling its VSL estimates in sensitivity analysis, while recognizing that more research is needed.

5.2.4 Summary of Recommendations

Based on the review in this report and related expert advice, we recommend a best VSL estimate of $6.1 million in 2007 dollars (prior to adjustment for income growth), with a 95 percent confidence interval of $4.8 million to $7.6 million and a normal distribution. While the source of these estimates differs from the sources cited by many Federal agencies, the estimates are within the $1.0 million to $10.0 million range defined in the OMB guidance.

These estimates should be adjusted for changes in real income over time, given the strong evidence that the VSL increases as income increases. The recent wage-risk studies suggest that the best estimate of the relationship between income and the VSL is an income elasticity of 0.47. In other words, for each 1.0 percent change in real income, the VSL is expected to increase by 0.47 percent. To assess uncertainty, these studies suggest that the 95 percent confidence interval for income elasticity ranges from 0.15 to 0.78, and is normally distributed. Again, these estimates are within the range of those used by other Federal regulatory agencies.

If adjusted for real income growth as well as inflation, the recommended mean VSL estimate increases to $6.3 million. For sensitivity analysis, $4.9 million and $7.9 million can be used as low and high values. (These numbers represent the 95 percent confidence interval estimates for the VSL, each adjusted for inflation and for real income growth using the mean elasticity estimate.) If probabilistic analysis is used instead, the base VSL estimates and the data used for the income adjustment can be entered as separate distributions, as discussed previously.

In addition, available studies suggest that individual willingness to pay may be significantly higher for terrorism-related risks than for risks from other causes, although there is substantial uncertainty regarding this relationship. This potential impact of this difference could be illustrated in sensitivity analyses. For example, based on the available research, this analysis could illustrate the implications of relying on a VSL estimate that is twice the estimate used in the main analysis; i.e., a mean value of $12.6 million (including the adjustments for inflation and income growth).

Some homeland security rules may affect different population subgroups or different types of risks, in which case the information in this report can be used to make appropriate quantitative adjustments to the VSL or to discuss related uncertainties in qualitative terms. In particular, if an attack is likely to lead to deaths from lingering illness (e.g., from exposure to radiological, biological, or chemical hazards), the VSL can be adjusted for any latency or time lag between exposure and incidence, and for the value of averting morbidity prior to death.

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APPENDIX A: DISTRIBUTION OF VISCUSI (2004) VSL ESTIMATES

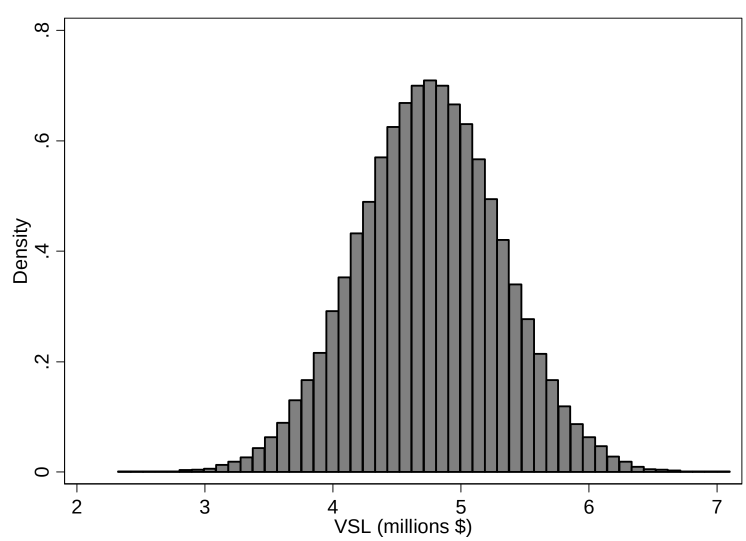
By: Dr. Joseph E. Aldy
Resources for the Future

This appendix describes the estimation of the distribution for the value of a statistical life drawn from Viscusi (2004), as discussed in Chapter 5 of this report. The reported mean in Viscusi (2004) is $4.7 million based on a coefficient estimate on the on-the-job mortality risk variable of 0.0017 and a standard error of 0.0002 (Table 3, full sample, mortality risk data by industry and occupation averaged over 1992-1997, controls for non-fatal injury and worker's compensation). Using the same source data file for workers' wages – the 1997 Current Population Survey Merged Outgoing Rotation Group dataset – I estimated the mean and variance for workers' hourly (or hourly equivalent) wages of $13.98 and 0.00052. I assume that the wage and the coefficient estimate are independent of each other and that they are both distributed normally. The product of two normally distributed variables is not normal, so I generated an empirical distribution to estimate the 95 percent confidence interval around the estimated VSL.

The empirical distribution is constructed by taking 100,000 random draws from two normal distributions based on the appropriate means and variances described above and then taking the product of each pair of draws. Exhibit A.1 illustrates the empirical distribution for the VSL.

Exhibit a.1

EMPIRICAL DISTRIBUTION OF THE VSL



Source: Analysis conducted by J. Aldy, based on Viscusi (2004).

This exhibit shows the standard outcome of taking the product of two normally distributed variables – a variable with a symmetric but slightly more peaked distribution than the normal. The empirical distribution has a mean VSL of $4.8 million (slightly larger than the reported value in Viscusi), a minimum of $2.3 million and a maximum of $7.1 million. The estimated 95 percent confidence interval is $3.7 million to $5.9 million. This confidence interval is virtually identical to the result of assuming that the product is normally distributed and using the estimated variance of the product based on Goodman (1960).

APPENDIX B: INCOME ELASTICITY CALCULATIONS

As discussed in Section 4.1.1 of this report, the value per statistical life (VSL) increases as income increases, and Federal agencies often adjust their VSL estimates to reflect changes in real income over time. In simple terms, these adjustments involve applying an estimate of income elasticity (i.e., the percent change in the VSL associated with a 1.0 percent change in income) to an estimate of the change in real income, then using the result to adjust the VSL – while also adjusting for inflation as needed.

The estimate of VSL income elasticity recommended for use in homeland security analyses is discussed in Section 5.2.3. This appendix provides more information on the related calculations. For simplicity, the examples in the appendix use the recommended best estimates for the VSL ($4.7 million in 1997 dollars) and for income elasticity (0.47), and focus on calculating the income- and inflation-adjusted VSL for the year 2007. A similar approach can be used to make these adjustments for the higher and lower estimates recommended for use in uncertainty analysis, and to update the estimates in future years.

The appendix first provides the data used to inflate the VSL estimates to 2007 dollars. These data are needed because the elasticity estimates apply to changes in real income (i.e., net of inflation). It then discusses the change in income over time, based on the Current Population Survey (CPS) data used in recent wage-risk studies. The third section then provides the equation used to apply the elasticity estimates, and the fourth section reports the results of the calculations.

B.1 Inflation Estimates

Because the elasticity adjustment applies to changes in real income (in constant dollars, net of inflation), data are needed on the effects of inflation over the time period of concern. Consistent with the approach generally used by Federal agencies and in most other analyses, this report uses the change in the Consumer Price Index – All Urban Consumers (CPI-U) for this purpose. For the time period 1997 to 2007, the relevant index values and the percent change for each period are provided in Exhibit B.1 below.

Exhibit B.1 CONSUMER PRICE INDEX – ALL URBAN CONSUMERS		
Year	**CPI – U**	**Percent Change from Prior Year**
1997	160.5	N/A
1998	163.0	1.6 percent
1999	166.6	2.2 percent
2000	172.2	3.4 percent
2001	177.1	2.8 percent
2002	179.9	1.6 percent
2003	184.0	2.3 percent
2004	188.9	2.7 percent
2005	195.3	3.4 percent
2006	201.6	3.2 percent
2007	207.3	2.8 percent
	Total Change, 1997-2007	**29.2 percent**
Source: U.S. Bureau of Labor Statistics, Consumer Price Index – All Urban Consumers (current series), http://www.bls.gov/CPI/, as viewed April 28, 2008.		

B.2 Estimates of Real Income Growth

The second input into the analysis involves estimating the change in real income over time. Earnings data are taken from the CPS, which is undertaken jointly by the Bureau of Census (in the U.S. Department of Commerce) and the Bureau of Labor Statistics (in the U.S. Department of Labor).[77] It is a monthly survey of about 50,000 households, and provides information on the characteristics of the labor force for the civilian, non-institutionalized U.S. population.

The CPS is the source of earnings data for recent U.S. wage-risk studies, as discussed in Chapter 3. It is used in the Viscusi (2004) study which is the basis of the VSL estimates recommended in this report. In addition, eight of the 30 U.S. labor market studies used to develop the income elasticity estimates (i.e., in Viscusi and Aldy 2003) use these data.[78]

More specifically, Viscusi (2004) is based on 1997 CPS data for nonagricultural workers who are not in the armed forces, focusing on full-time workers with usual hours of 35 or more per week, aged 18 through 65. Viscusi excludes workers with wages below the statutory minimum as well as with high earnings (above $100,000 per year), and also excludes workers

[77] More information on this survey as well as access to the resulting data are provided at: http://www.census.gov/cps/ or http://www.bls.gov/cps/home.htm.
[78] The elasticity estimates from Viscusi and Aldy (2003) are based on both the U.S. and non-U.S. labor market studies.

with less than a 9th grade education. In the regression analyses used to estimate the relationship between wages and risks, Viscusi (2004) specifies hourly wages in log form. The log of wages was also used in many of the models developed to estimate income elasticity in the Viscusi and Aldy (2003) meta-analysis.

While it is not possible to exactly match the Viscusi (2004) sample without manipulating the underlying datasets for the years of interest, the Bureau of Labor Statistics routinely publishes CPS data on median weekly earnings per worker. Exhibit B.2 provides related data.

Exhibit B.2

MEDIAN WEEKLY EARNINGS: CURRENT POPULATION SURVEY[a]

Year	Current Dollars[a]	Constant (1997) Dollars[b]	Change from Prior Year (constant 1997 dollars)
1997	$503	$503	N/A
1998	$523	$515	2.38 percent
1999	$549	$529	2.70 percent
2000	$576	$537	1.51 percent
2001	$596	$540	0.61 percent
2002	$608	$542	0.43 percent
2003	$620	$541	-0.30 percent
2004	$638	$542	0.23 percent
2005	$651	$535	-1.31 percent
2006	$671	$534	-0.15 percent
2007	$695	$538	0.71 percent
		Total Change, 1997-2007	**6.96 percent**

Sources: Current Population Survey data provided in current dollars via email by Emy Sok, U.S. Bureau of Labor Statistics, April 28, 2008.
Notes:
a. Reflects annual averages for median usual weekly earnings of full-time wage and salary workers.
b. Deflated to constant 1997 dollars by the author, using the CPI-U data from Exhibit B.1.

As indicated by the exhibit, the CPS suggests that median weekly earnings have changed by varying amounts from year-to-year, increasing by less than three percent in some years and decreasing by more than one percent in others. Over the time period assessed, real earnings increased by roughly seven percent when expressed as constant (1997) dollars.

While the data provided by the CPS are sufficient to adjust the VSL estimate to the base dollar year used in homeland security regulatory analyses, they do not include projections for future years. More research would be needed to identify a source that could be used to predict future year values, in cases where the regulatory analyses predict differing levels of costs and benefits in future years.

B.3 Equation for Income Adjustments

In simple terms, income elasticity is often calculated as if it were a point estimate. If:

x = real income
y = the VSL
η = income elasticity

then η = the percent change in y divided by the percent change in x, or

$$\eta = \left[\frac{y_2 - y_1}{y_1}\right] \div \left[\frac{x_2 - x_1}{x_1}\right]$$

However, this formula is sensitive to the starting point; i.e., the results may vary if x_2 and y_2 (instead of x_1 and y_1) are used as the divisors, particularly if there is a large difference between the two values. One option for addressing this issue is to calculate the arc elasticity from the mid-point of the range for both x and y; e.g., by replacing the x_1 in the denominator by $(x_1+x_2)/2$.

A more exact approach involves using a logarithmic formula for calculating the arc elasticity. The derivation of this formula is provided in Exhibit B.3.

Exhibit B.3

CALCULATION OF VSL INCOME ADJUSTMENT

Elasticity (η) is defined as the ratio of the proportional change in an outcome variable (y) divided by the ratio of the proportional change of an input variable (x). Now let x denote real income, y denote the VSL, and η be the income elasticity; i.e.,

$$\eta = \frac{dy/y}{dx/x}. \qquad (1)$$

Multiplying by the denominator of the right-hand side yields

$$\frac{dy}{y} = \eta \frac{dx}{x}. \qquad (2)$$

This is a differential equation, the solution to which is

$$\log(y) = \eta \log(x) + k \qquad (3)$$

where log means natural logarithm and k is an arbitrary constant. Exponentiating both sides yields

$$y = Kx^{\eta} \qquad (4)$$

where $K = e^k$.

Using equation (4),

$$y_2 = Kx_2^{\eta} \qquad (5)$$

and

$$y_1 = Kx_1^{\eta}. \qquad (6)$$

Dividing equation (5) by equation (6) yields

$$\frac{y_2}{y_1} = \left[\frac{x_2}{x_1}\right]^{\eta} \qquad (7)$$

and multiplying by y_1 yields

$$y_2 = y_1\left[\frac{x_2}{x_1}\right]^{\eta}. \qquad (8)$$

Source: Provided by Dr. James K. Hammitt, April 28, 2008.
Note: This derivation assumes that income elasticity is constant (i.e., does not vary with income).

B.4 Calculation of Inflation and Income Adjusted VSL

The final step involves using the data and equation provided above to adjust the VSL for both inflation and income growth. The inputs into this calculation include the following:

VSL, 1997 dollars = $4.7 million (from Viscusi (2004), see Section 5.2.2)
Inflation, 1997-2007 = 29.2 percent (from Exhibit B.1)
Real income growth, 1997-2007 = 6.96 percent (from Exhibit B.2)
VSL income elasticity = 0.47 (from Viscusi and Aldy 2003, see Section 5.2.3)

Substituting into the above formula and multiplying by inflation leads to the results below.

$$\text{VSL (2007)} = \$4.7 \text{ million } (1.292)(1.0696)^{0.47}$$

$$= \$6.3 \text{ million.}$$

Hence adjusting for inflation and income growth leads to a VSL of $6.3 million in 2007 dollars, whereas adjusting for inflation only leads to a VSL of $6.1 million.